## 2.12 CLUTTER

Clutter may be defined as the signal return from unintended targets. Although radar clutter signals may be reflections from unintended targets such as rain, insects, and space debris, the most significant clutter signals are due to reflections from the earth's surface. The intensity of the clutter echo is calculated using the standard radar equation, with target cross section replaced by the effective radar cross section of the illuminated clutter object.

The effective radar cross section of the clutter patch (so) is the product of the ground area being illuminated by the radar and the reflection coefficient of the earth's surface.

The reflection coefficient is the reflectivity of the earth's surface relative to a perfectly reflecting surface normal to the radar beam and is typically an empirically derived value dependent upon the surface characteristics. Several organizations have sporadically measured the reflectivity of the earth's surface. MIT Lincoln Laboratories has the largest ground clutter reflectivity data base, having measured the reflectivity of an array of ground surfaces. They have characterized ground reflectivity as a function of ground roughness, ground cover, frequency, and grazing angle. Sea clutter reflectivity has been measured by others and is typically characterized as a function of sea state (sea surface roughness), salinity, water temperature, grazing angle, and transmit frequency.

The illuminated area is typically represented as a segment of a circular area, bounded by the azimuthal antenna beam width and range illuminated during a single pulse. For high-PRF radars, having ambiguous ranges within the radar horizon, several clutter patches may be illuminated and the clutter signals from each ambiguous range cell contribute to the total clutter signal.

Ground clutter signal returns are considered as reflections from nearly stationary objects, relative to the target signal, and therefore experience little Doppler frequency shift. It is this signal characterization that allows for discrimination of received target signals from clutter signals.

Clutter signals propagate in the same manner as target signals. They are subject to clutter patch masking by intervening terrain and the same near earth and atmospheric propagation effects as the target signal.

### 2.12.1 Functional Element Design Requirements

This section contains the design requirements to fully implement the clutter simulation.

a. The Clutter Functional Element will simulate the effects of specular surface clutter as a radar interference signal.

b. ESAMS will represent the clutter function using two different algorithms: a) The "native" algorithm using the Georgia Tech clutter code (originally installed in the TAC ZINGER models) modified to use digital triangular terrain data, (References 1 & 2); and b) the GRACE (Ground Radar Clutter Estimator) algorithm, using clutter scattering models developed by MIT Lincoln Laboratory (Reference 3). The choice of algorithm is to be user- selectable.

c. The clutter simulation is to be applicable to both acquisition and track radars. Seeker clutter simulation is to be allocated to a different functional element using algorithms more adaptable to platform motion.

d. The Clutter Functional Element will allow for user-selectable terrain form and terrain cover.

e. ESAMS will compute clutter returns to the radar horizon, based upon a 4/3 earth radius approximation to account for refraction effects.

f. ESAMS will simulate the effects of clutter patch masking by intervening terrain.

g. ESAMS will calculate clutter returns over antenna azimuth segments that significantly contribute to the total clutter signal. The user-selected clutter acceptance zone may provide both main lobe and side lobe contributions.

h. Although the clutter horizon is determined by a round smooth earth approximation, other clutter computations will assume a flat earth.

i. ESAMS will account for clutter returns from ambiguous range cells.

## 2.12.2 Functional Element Design Approach

This section discusses the design approach used to implement the design requirements outlined in the previous section. The discussion will be in two parts to describe the design approach for the native and GRACE algorithm implementations respectively.

### Native Clutter Model

### Design Element 12-1: Clutter Signal in Sum and Difference Channels

The ESAMS radar simulation is primarily concerned with ground based target tracking radars such that signal returns are received only during the time that the range gate is open. Clutter signal returns are from ground illumination at the unambiguous target range and from ambiguous target ranges corresponding to multiples of the pulse repetition interval (PRI). ESAMS simulates a monopulse type angle tracking radar and the clutter signal return is calculated for both sum and difference channels. For the sum channel, the clutter signal contribution from each clutter resolution cell is expressed as:

$$C_{\Sigma} = \sum_{i} \frac{P_i \lambda^2 G_{\Sigma i}^4 \sigma_i^0 A_i}{(4\pi)^3 R_i^4 X_{loss}} \qquad [2.12\text{-}1]$$

This equation is the summation of clutter power from multiple clutter cells. The standard equation for clutter power is found in most radar reference books; e.g., Reference 27, equation 2.3.4, page 72. For the azimuth difference channel, the clutter signal is “signed.” The azimuth clutter signal is expressed as:

$$C_{azdiff} = \sum_{i} \frac{P_i \lambda^2 G_{\Xi i}^2 G_{\Delta AZ_i}^2 S\left(G_{\Delta AZ_i}\right) \sigma_i^0 A_i}{(4\pi)^3 R_i^4 X_{loss}} \qquad [2.12\text{-}2]$$

where $P_t$ = power transmitted

$\lambda$ = radar wavelength

$G_{\Sigma_i}$ = antenna gain in direction of clutter cell *i* for sum channel

$G_{\Delta AZ_i}$ = antenna gain in direction of clutter cell $i$ for azimuth difference channel

$S\left(G_{\Delta AZ_i}\right)$ = sign of difference channel gain

$\sigma_i^0$ = clutter reflectivity of cell $i$

$A_i$ = surface area of cell $i$

$R_i$ = range to cell $i$

$X_{loss}$ = receiver loss factor

The clutter signal received in the elevation difference channel is expressed similarly with $G_{\Delta AZ_i}$ replaced with $G_{\Delta EL_i}$ throughout.

### Design Element 12-2: Range Ambiguity

For range gated radars, clutter signals may be received at the time the range gate is open. Thus clutter will be received not only from the ground illuminated at the target range but also from ground illuminations at ambiguous ranges, ranges that are integral multiples of the target range. It is necessary to sum the clutter contributions from the unambiguous and ambiguous range cells within the radar clutter horizon. ESAMS first determines if the intersection of the clutter acceptance cone with the terrain is within the radar horizon. The minimum possible range is determined as

$$R_m = \frac{h_a}{\sin\theta_{EL}} \qquad [2.12\text{-}3]$$

where $\theta_{EL}$ = elevation acceptance cone angle relative to horizontal

$h_a$ = antenna height

ESAMS determines the unambiguous range $R_u$ as (Reference 6, page 234):

$$R_u = \frac{c\tau_r}{2} \qquad [2.12\text{-}4]$$

where c = speed of light (m/sec)

$\tau_r$ = pulse repetition interval = 1/PRF (sec)

The clutter signal computations are looped over all possible ranges ($R_i$) determined by

$$R_i = R_g + iR_u \qquad [2.12\text{-}5]$$

for all integers: such that

$$0 \le R_g + iR_u \le R_h \qquad [2.12\text{-}6]$$

where $R_g$ = range to range gate center (m)

$R_h$ = range to horizon (m)

The integer $i$ is called the range ambiguity index.

The clutter horizon is approximated using the four-thirds earth correction for refraction and is expressed as (Reference 6, page 41):

$$R_h = (2 \times 1.333 \times R_e \times h)^{1/2} \qquad [2.12\text{-}7]$$

where $R_e$ = earth radius (m)

$h$ = height of antenna (m)

### Design Element 12-3: Clutter Patch Area

In ESAMS, the illuminated clutter patch is defined as the area contained within an arc segment limited by the range illuminated during the range gate. The arc width is defined by first constructing an acceptance cone whose centerline is along the antenna boresight axis with the apex at the radar antenna and the base at the clutter horizon.

The half angle of the cone is a user-defined input value. The azimuth limits of the clutter patch are then defined as the intercept angle of the bottom side of the cone with the earth's surface, assumed as a flat plane. The acceptance cone intersection with the terrain surface is illustrated in Figure 2.12-1. As shown in Figure 2.12-2, the clutter arc segment is then further segmented into resolution cells, having arbitrary user-input terrain resolution.

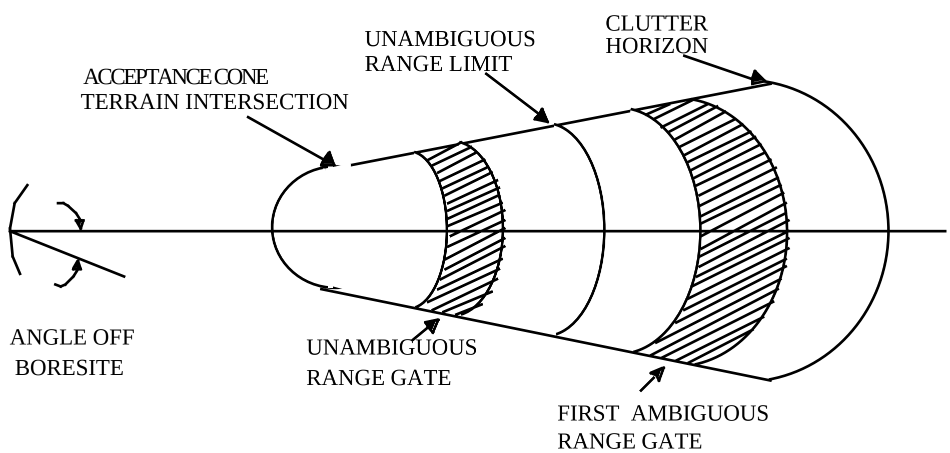



FIGURE 2.12-1. Terrain Limits for Clutter Integration.

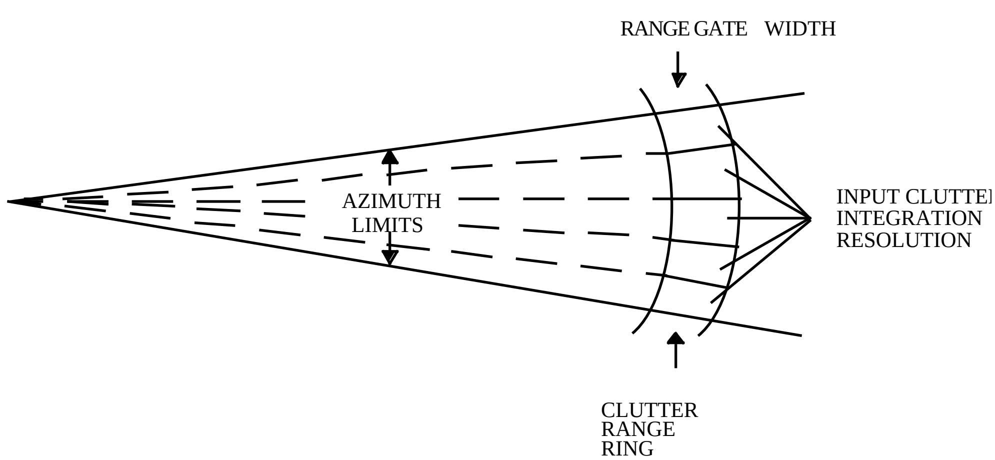



FIGURE 2.12-2. Integration Cells for Clutter.

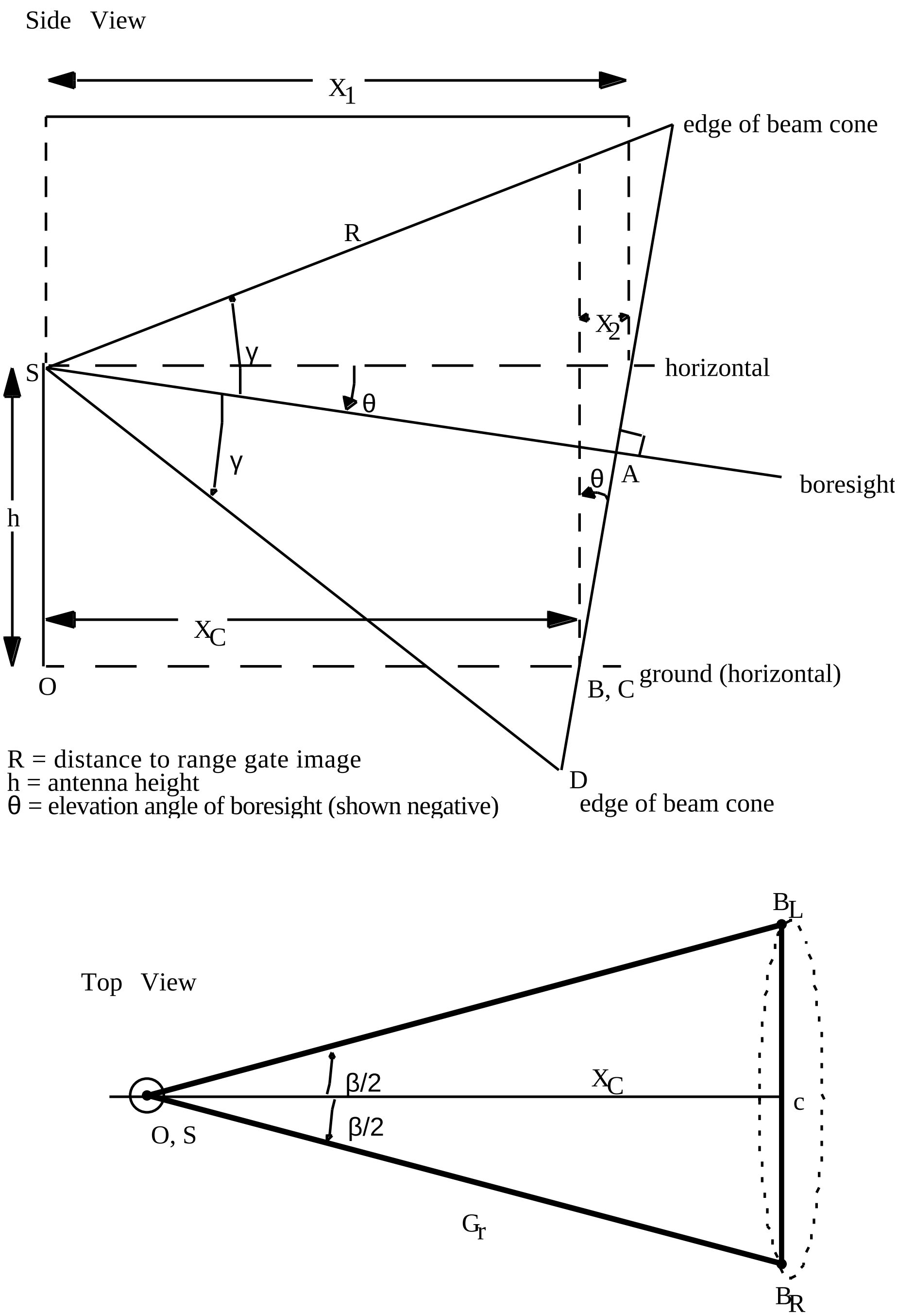



FIGURE 2.12-3. Geometry for Azimuth Limits (+β/2) in Clutter Integration.

Figure 2.12-3 illustrates the geometry used to determine the azimuth limits. The user-defined half-angle of the cone is denoted by γ, the half-angle of the intersection of this cone with the ground is denoted by β/2. To find β/2, it is first necessary to determine the distance $X_c$. From the figure, it is clear that

$$X_c = X_1 - X_2 \qquad [2.12\text{-}8]$$

X1 and X2 can be calculated by applying basic rules of geometry and trigonometry.

$$X_1 = \frac{R\cos(\gamma)}{\cos(-\theta)} \qquad [2.12\text{-}9]$$

$$X_2 = h\tan(-\theta) \qquad [2.12\text{-}10]$$

where $\theta$ = the antenna boresight elevation angle
$\gamma$ = the cone apex half-angle
$R$ = range to the range gate
$h$ = antenna height

Thus, the value of $X_c$ is

$$X_c = \frac{R\cos(\gamma)}{\cos(-\theta)} - h\tan(-\theta)$$

$$X_c = \frac{R\cos(\gamma)}{\cos(\theta)} + h\tan(\theta) \qquad [2.12\text{-}11]$$

The next step is to calculate the ground range ($G_r$), which can be expressed as

$$G_r = \sqrt{R^2 + h^2} \qquad [2.12\text{-}12]$$

The off-boresight azimuth angle limits for clutter calculations can be expressed as

$$\frac{\beta}{2} = \cos^{-1}\left(\frac{X_c}{G_r}\right) \qquad [2.12\text{-}13]$$

and the azimuth angle limits of the clutter patch are

$$\varphi_{\mathrm{min}} = \theta_{\mathrm{az}} - \frac{\beta}{2} \qquad [2.12\text{-}14]$$

$$\varphi_{\mathrm{max}} = \theta_{\mathrm{az}} + \frac{\beta}{2} \qquad [2.12\text{-}15]$$

where $\theta_{az}$ = azimuth angle of boresight

The angular width of the resolution cells within the azimuth angular limits is computed by first calculating the number of intervals (N) to get the desired resolution.

$$N = \mathrm{INT}\left(\frac{\beta R}{R_{\mathrm{res}}} + .5\right) \qquad [2.12\text{-}16]$$

where $\beta$ = azimuth angle width

$R$ = range to clutter

$R_{res}$ = terrain resolution

If $N$ is an even number, $N$ is set to an odd number.

$$N = N + 1 \qquad [2.12\text{-}17]$$

If $N$ is less than 3, then

$$N = 3 \qquad [2.12\text{-}18]$$

The angle difference ($\Delta\theta_{AZ}$) between resolution cell is

$$\Delta\theta_{AZ} = \frac{\beta}{N} \qquad [2.12\text{-}19]$$

Finally, to determine the radial length of the clutter patch range ring, the projection of the range gate width $R_{WD}$ can be expressed as

$$R_{WD} = \frac{c\tau}{2\cos(\theta_{el})} \qquad [2.12\text{-}20]$$

where $c$ = speed of light (m/sec)

$\tau$ = transmit pulse width (sec)

$\theta_{el}$ = boresight elevation angle

The clutter area of the resolution cell can be expressed as:

$$A = R_{WD} R \,\Delta\theta_{AZ} \qquad [2.12\text{-}21]$$

The last two equations are consistent with the pulse length limited case documented by Nathanson (Reference 27, Equations 2.36 & 2.38).

### Design Element 12-4: Clutter Reflectivity - Native Mode

ESAMS determines the clutter reflectivity ($\sigma°$) for the current clutter cell for any of twelve, user selected, types of terrain clutter. For clutter type 1, described as Georgia Tech sea clutter, the depression angle from the radar to the clutter cell, is first determined as

where $h_a$ = antenna height (m)

$$\gamma_i = \sin^{-1}\left(\frac{h_a - h_c}{R_{clut}}\right) \qquad [2.12\text{-}22]$$

where $h_a$ = antenna height

$h_c$ = clutter height (m)

$R_{clut}$ = range to the clutter cell (m)

The sea clutter reflectivity coefficient is then determined from the following empirically derived relationship (Reference 12):

$$\sigma^{o} = 1.1 \text{ x } 10^{-5}\lambda^{1.25}\lambda^{0.4}(\lambda + 0.001)^{0.29}(h_{av} + 0.05)^{-0.24} A_i A_w \qquad [2.12\text{-}23]$$

where
- $\lambda$ = wavelength of the transmit frequency (ft)
- $h_{av}$ = wave factor = 0.63 x wave height (ft)
- $\gamma$ = grazing angle
- $A_w$ = wind speed factor
- $A_i$ = interference factor

[Note to Developer: The coded equation uses the wavelength ($\lambda$) raised to the .25 power, rather than 1.25 as shown in the GTRI published equation.]

The wind speed factor is calculated as

$$A_w = \left[\frac{V_w}{1 + \frac{V_w}{30}}\right]^{qw} \qquad [2.12\text{-}24]$$

where the wind speed Vw is expressed as

$$V_W = (10.47h_{av})^{0.4} \text{ (knots)} \qquad [2.12\text{-}25]$$

and the wind speed factor exponent (qw) is expressed as

$$qw = 1.7(\lambda + 0.05)\text{-}0.4 \qquad [2.12\text{-}26]$$

The interference factor ($A_i$) is determined from the following expression

$$A_i = \frac{\sigma_\varphi^4}{(1 + \sigma_\varphi)^4} \qquad [2.12\text{-}27]$$

where the dimensionless roughness factor ($\sigma_\varphi$) is expressed as:

$$\sigma_\varphi = \frac{(4.4\lambda + 5.5)\gamma h_{av}}{\lambda} \qquad [2.12\text{-}28]$$

[Note to Developer: In the code, the interference factor appears to be expressed as:

$$A_i = \frac{\sigma_\varphi^4}{(1 + \sigma_\varphi^4)} \qquad [2.12\text{-}29]$$

## Design Element 12-5: Land Clutter Coefficient — Native Mode

Clutter types 2 through 9 are Georgia Tech land clutter types, described sequentially as soil, grass, crops, trees, sand, rocks, urban, and wet snow. For these cases, the clutter reflectivity is determined from the following empirically derived expression (Reference 5):

$$\sigma^{o} = A(\gamma + C)^{B} \exp\left(\frac{-D}{1 + 0.03\sigma_h}\right) \qquad [2.12\text{-}29]$$

where $\gamma$ = grazing incidence angle (radians)
$\sigma_h$ = surface standard deviation (cm)

The coefficients A, B, C, D are a function of terrain type and transmit frequency as tabulated in Table 2.12-1.

TABLE 2.12-1. Georgia Tech Clutter Model Parameters.
(Source: Reference 3)

| TERRAIN TYPE | A | | | | B | C | D |
|---|---|---|---|---|---|---|---|
| **Frequency (Ghz)** | **15.0** | **9.5** | **5.0** | **3.0** | **ALL** | **ALL** | **ALL** |
| 1. Sea | (Sea Clutter Parameterized Differently) | | | | | | |
| 2. Soil | 0.036 | 0.025 | 0.015 | 0.0099 | 0.83 | 0.0013 | 2.3 |
| 3. Grass | 0.056 | 0.039 | 0.0089 | 0.015 | 1.5 | 0.012 | 0.0 |
| 4. Crops | 0.056 | 0.039 | 0.0089 | 0.015 | 1.5 | 0.012 | 0.0 |
| 5. Trees | 0.0043 | 0.003 | 0.0018 | 0.0012 | 0.64** | 0.002 | 0.0 |
| 6. Sand | 0.036 | 0.025 | 0.015 | 0.0099 | 0.83 | 0.0013 | 2.3 |
| 7. Rocks | 0.036 | 0.025 | 0.015 | 0.0099 | 0.83 | 0.0013 | 2.3 |
| 8. Urban | 2.878 | 2.0 | 1.194 | 0.791 | 1.8 | 0.015 | 0.0 |
| 9. Wet Snow | 0.014 | 0.0097 | 0.0058 | 0.0038 | 1.7 | 0.0016 | 0.0 |

For terrain types 2 through 9, the clutter reflectivity is increased by 5.0 dB for wet terrain. Types 10 through 12 use Lincoln Laboratory reflectivity for ground clutter for three terrain types, Rural/Low-Relief, Rural/High-Relief, and General Urban.

For Lincoln Laboratory, the reflectivity, is a function of the grazing angle and the transmit frequency as well as the terrain type. For terrain types 10 through 12, ESAMS uses the interpolated tabular values for reflectivity as shown in Table 2.12-2, Lincoln Laboratory Ground Clutter Parameters.

## Design Element 12-6: Terrain Shadowing — Native Mode

In the native clutter model, ESAMS does not explicitly use the digital triangular terrain to determine clutter masking by intervening terrain. Rather it uses a “non-site-specific” mean terrain visibility factor to reduce the clutter return “on the average.” The visibility factor used in ESAMS is derived from Lincoln Laboratory estimates of the percent of illuminated clutter patch circumference in clutter as a function of the range to clutter, for various

TABLE 2.12-2. Lincoln Laboratory Ground Clutter Parameters.
(Source: Reference 4)

| TERRAIN TYPE | DEPRESSION ANGLE (deg) | $\alpha_w^o$ (dB) FREQUENCY BAND | | | | | $\alpha_w$ RESOLUTION ($m^2$) | |
|---|---|---|---|---|---|---|---|---|
| | | VHF | UHF | L-BAND | S-BAND | X-BAND | $10^3$ | $10^6$ |
| Rural/Low-Relief General Rural | 0.00 to 0.25 | -33 | -33 | -33 | -33 | -33 | 3.8 | 2.5 |
| | 0.25 to 0.75 | -32 | -32 | -32 | -32 | -32 | 3.5 | 2.2 |
| | 0.27 to 1.50 | -30 | -30 | -30 | -30 | -30 | 3.0 | 1.8 |
| | 1.50 to 4.00 | -27 | -27 | -27 | -27 | -27 | 2.7 | 1.6 |
| | >4.00 | -25 | -25 | -25 | -25 | -25 | 2.6 | 1.5 |
| Rural/High-Relief General Rural | 0 to 2 | -27 | -27 | -27 | -27 | -27 | 2.2 | 1.4 |
| | 2 to 4 | -24 | -24 | -24 | -24 | -24 | 1.8 | 1.3 |
| | 4 to 6 | -21 | -21 | -21 | -21 | -21 | 1.6 | 1.2 |
| | >6 | -19 | -19 | -19 | -19 | -19 | 1.5 | 1.1 |
| Urban General Urban | 0.00 to 0.25 | -20 | -20 | -20 | -20 | -20 | 4.3 | 2.8 |
| | 0.25 to 0.75 | -20 | -20 | -20 | -20 | -20 | 3.7 | 2.4 |
| | >0.75 | -20 | -20 | -20 | -20 | -20 | 3.0 | 2.0 |

effective antenna heights. The visibility factors for various antenna heights were obtained by fitting the curves of Reference 4, Figure 1-5 to the power law expression.

$$f_{vis}(h,R) = C(h)^{-R} \qquad [2.12\text{-}30]$$

where $h$ = antenna height above the terrain (m)
$R$ = range to the clutter (km)

Values of $C$ as a function of antenna height above the terrain are in tabular form. The reflectivity adjusted for mean visibility factor is simply:

$$\sigma_{vis}^o = f_{vis}\sigma^o \qquad [2.12\text{-}31]$$

## Design Element 12-7: Clutter Power Summation and Conversion

The final steps in the determination of the total clutter power are to sum the clutter power from all range rings, retaining the sign for the elevation and azimuth difference channels (Equations [2.12-1] and [2.12-2]). Finally, the power is converted to a complex voltage. For this conversion, the phase angle is arbitrarily set to 0.0°.

[Note to Developer: If the phase angle is set to 0.0°, the scale factor is real not complex. Is this what you really want?]

The complex sum channel clutter voltage is expressed as

$$V_{csum} = \left(\sqrt{P_{csum}} + j\sqrt{P_{csum}}\right)\left(cos(\varphi) + j\,sin(\varphi)\right) \qquad [2.12\text{-}32]$$

where $P_{csum}$ = the accumulated sum channel power

$\varphi$ = phase angle = 0.0 deg

The difference channel clutter voltage is similarly expressed except the sign of the difference clutter voltage is retained.

### Grace Clutter Model

The computation of clutter signals, using the GRACE clutter mode, is identical to that used for the native clutter mode with three exceptions.

1. Terrain reflectivity is pre-calculated in the Ground Clutter Estimator (GRACE) and stored in an array of range/azimuth cells.
2. The height of the terrain at the X, Y location of the clutter patch is computed from the GRACE triangular terrain data base.
3. In constructing the terrain reflectivity array, GRACE determines if the terrain cell is masked by intervening terrain and, if masked, sets the reflectivity to a small value (–90 dB).

GRACE is not a functional part of ESAMS but serves merely as a data base from which to retrieve terrain reflectivity and terrain height used by ESAMS for the computation of clutter signal amplitude. GRACE is therefore outside the scope of the Post Development Design Documentation for ESAMS but it is essential to generally understand GRACE in order to determine the ESAMS interfaces necessary to retrieve desired GRACE data. In GRACE, a site mask map is created from the terrain surrounding each site. Additionally, for each site, a backscatter coefficient is calculated for each resolution cell within the visible regions of the ground surface surrounding the site. The backscatter coefficient is determined using DMA DTED terrain and Lincoln Laboratory clutter reflectivity data, which are a function of terrain relief, terrain cover, antenna depression angle, and radar frequency. For resolution cells that are masked by intervening terrain, the reflectivity is set to a very low value.

### Design Element 12-8: Coordinate Conversion for GRACE

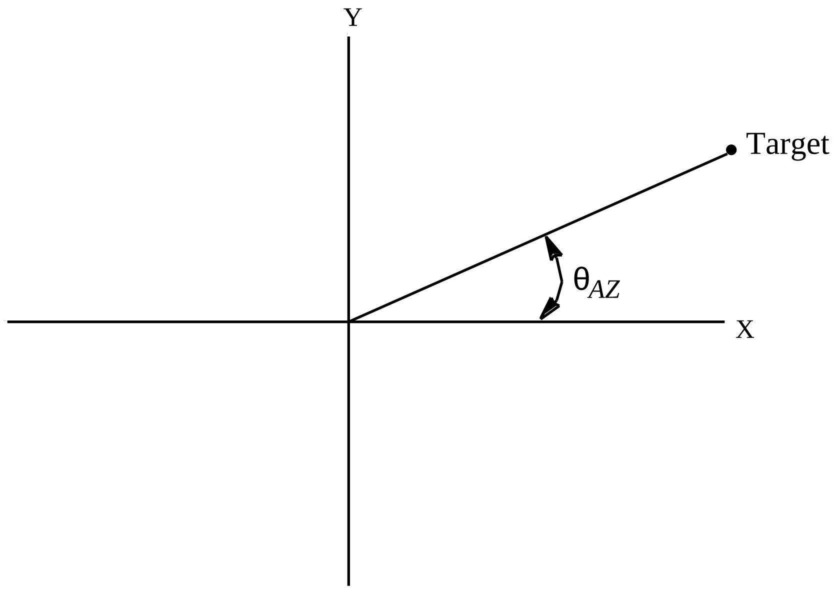
Before the first call to GRACE, ESAMS uses the target azimuth in ESAMS coordinate system to find the target azimuth relative to true north.

Figure 2.12-4 shows the relationship between the ESAMS azimuth coordinate system and true azimuth. It is obvious from geometry that the true target azimuth relative to ESAMS coordinates can be expressed as

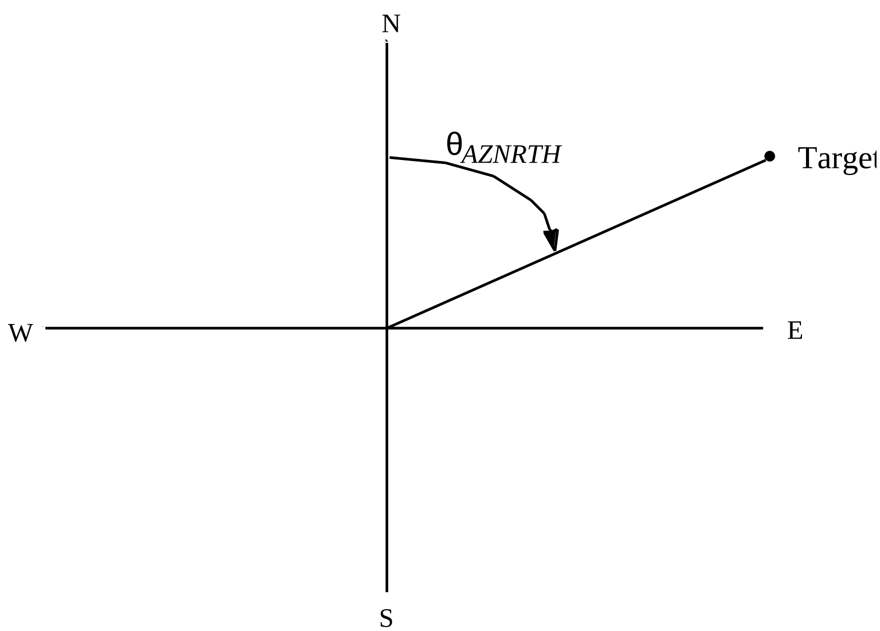
FIGURE 2.12-4. Relationship of ESAMS Coordinate System and True North Geographical System.

$$\theta_{AZNRTH} = \left(\frac{5\pi}{2} - \theta_{AZ}\right) - \left\| \frac{5\pi/2 - \theta_{AZ}}{2\pi} \right\| 2\pi \qquad [2.12\text{-}33]$$

where || || denotes the largest integer function.




ESAMS Coordinate System
and ESAMS Azimuth $\theta_{AZ}$




Geographic Coordinate System
and True Azimuth $\theta_{AZNRTH}$

Having determined the true azimuth position and range to the clutter, the GRACE data base is entered to retrieve the pre-computed value of reflectivity for the designated azimuth and range cell.

The terrain altitude for the designated range and azimuth cell is also retrieved from the GRACE data base and if the target flight paths are curved earth paths, the tangent plane altitude is computed as

$$Z_{tan} = Z_{sl} - \frac{.5\left(X^2 + Y^2\right)}{R_e} \qquad [2.12\text{-}34]$$

where $R_e$ = radius of the earth
$Z_{sl}$ = altitude of the clutter cell referenced to sea level
X,Y = coordinates of the clutter cell

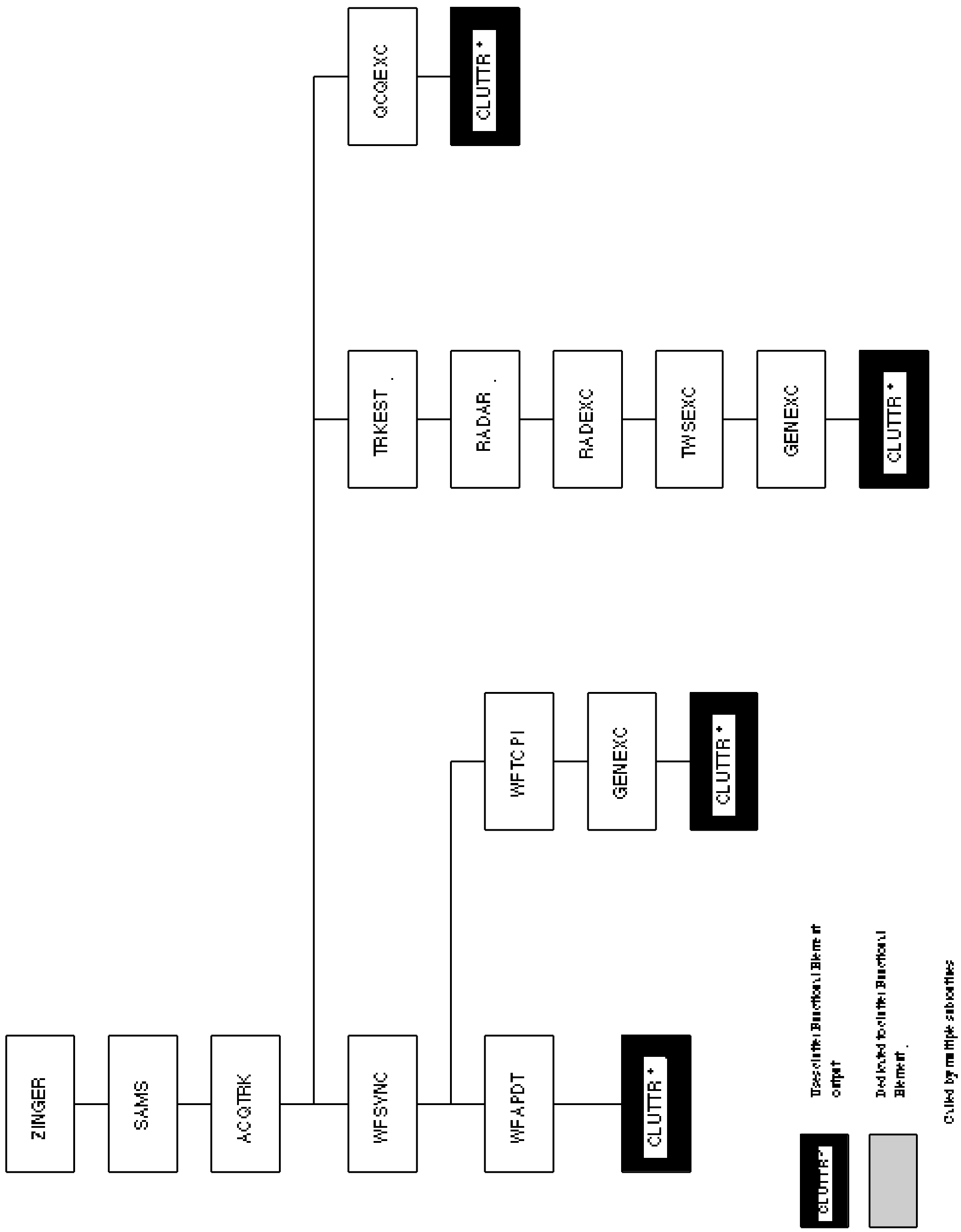
The terrain altitude is used to determine the antenna gain in the direction of the clutter patch, identically as is done in the native clutter mode.

## 2.12.3 Functional Element Software Design

This section describes the software design necessary to implement the functional element requirements outlined in Section 2.12.2 and the design approach outlined in Section 2.12.3. Section 2.12.4 is organized as follows: The first part describes the subroutine hierarchy and gives descriptions of the relevant subroutines, the next part contains functional flow charts and describes all important operations represented by each block in the charts, the third part presents detailed logical flow charts for the subroutines, and the last part contains a description of all input and output data for the functional element as a whole and for each subroutine which implements clutter.

### Clutter Subroutine Hierarchy

The FORTRAN call tree that will be implemented for the Clutter Functional Element in the ESAMS 6.2 source code is shown in Figure 2.12-5. The diagram depicts the entire model structure from ZINGER (the main program) through the least significant subroutine in the Clutter Functional Element. Subroutines which directly implement the functional element appear as shaded blocks. Subroutines which use functional element results appear with bands at the ends. Each of these subroutines is briefly described in Table 2.12-3.


ZINGER
SAMS
ACQTRK
WFSYNC
WFAPDT
CLUTTR*
WFTCPI
GENEXC
CLUTTR*
TRKEST
RADAR
RADEXC
TWSEXC
GENEXC
CLUTTR*
QCQEXC
CLUTTR*
CLUTTR*
Uses clutter Functional Element output
Dedicated to clutter Functional Element
Called by multiple subroutines

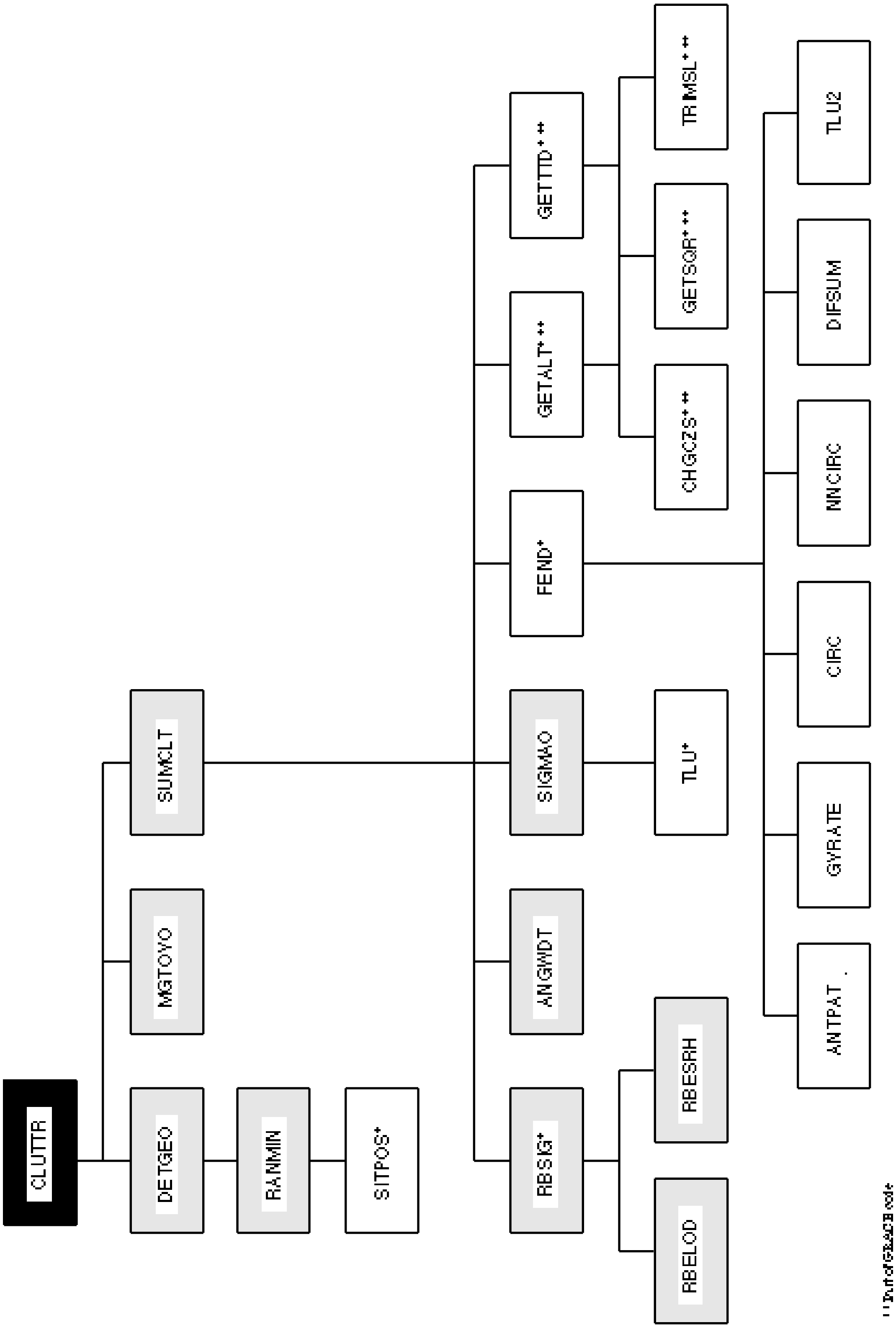



FIGURE 2.12-5. Call Hierarchy for Clutter. (Contd)

TABLE 2.12-3. Subroutine Descriptions.

| MODULE NAME | DESCRIPTION |
|---|---|
| ANGWDT | Provides azimuth interval between azimuth limits |
| ANTPAT | Determines antenna gain from look-up table |
| CLUTTR | Main clutter subroutine |
| CHGC2S | Provides lat/long from XY coordinates |
| CIRC | Calculates gain for circular antenna beam |
| DETGEO | Determines if minimum range is inside radar horizon |
| DIFSUM | Calculates sum/difference antenna patterns |
| FEND | Provides antenna gain in a given direction |
| GETALT | Retrieves altitude of terrain point |
| GETSQR | Retrieves terrain parameters for particular terrain cell |
| GETTTD | Calculates triangular terrain data for surface point |
| GYRATE | Performs coordinate transformation into antenna reference plane. |
| MGTOVO | Changes clutter power to complex voltages |
| NNCIRC | Calculates antenna gain for non-circular beam |
| RANMIN | Calculates minimum possible range for clutter evaluations |
| RBELOD | Loads backscatter data into RF Backscatter Estimator file |
| RBESHR | Finds azimuth offset of clutter patch |
| RBSIG | Retrieves RF Backscatter value for given azimuth and range |
| SIGMAO | Determines clutter reflectivity of current clutter cell |
| SUMCLT | Determines total clutter power from all clutter cell contributors |
| TLU | Looks up table values for terrain reflectivity |
| TRIMSL | Provides lat/long and altitude of terrain point |

### Clutter Functional Flow — Native Mode

Figure 2.12-6 shows the logical flow of the Clutter Functional Element as implemented for both the native and GRACE clutter modes. Subroutine names appear in parentheses at the bottom of each process block. The numbered blocks are described below. Detailed logical flow charts for the subroutines will be presented later in this section.

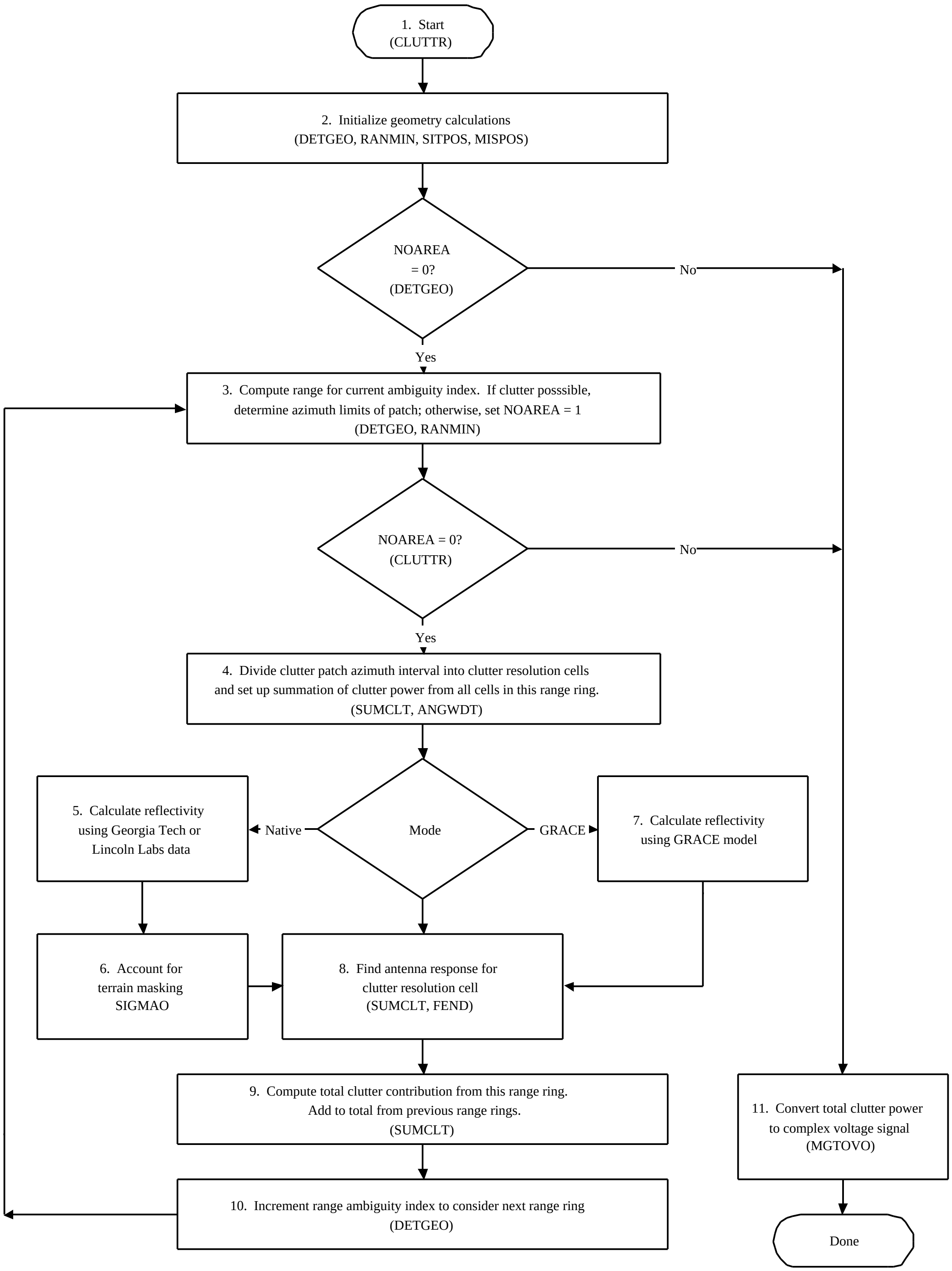



FIGURE 2.12-6. Clutter Functional Flow.

Block 1. CLUTTR is the main subroutine which controls the computation of clutter. Computation of clutter is enabled by subroutine SAMS which calls subroutine CLRFLG to determine if the user chooses to calculate clutter. If "noise" is "off," clutter is not to be calculated and subroutine CLRFLG sets the clutter flag, KCLFL = 0. If noise is "on," the clutter flag is set to an integer value (determined by subroutine INICLT) which is a function of the radar type. Additionally INICLT does some unit conversions, calculates some common variables, and initializes some variables to be used for clutter computations. To begin the clutter signal computation, the summation of clutter power, at the sum and difference receiver channels, is initialized to zero.

Block 2. Subroutine DETGEO is called several times by CLUTTR to determine the clutter patch geometry. The first call to DETGEO serves to initialize the geometry calculations. On the first pass through the range image loops, DETGEO calls subroutine RANMIN to determine if the minimum possible range, that is the range to the intersection of the acceptance cone with the terrain, is within the radar horizon. and if so, which range gate image is at the minimum possible range. On subsequent passes through the range image loop, DETGEO skips the call to RANMIN and merely steps the range image index to the next value.

Subroutine RANMIN does the processing to determine the minimum possible range to clutter, indexes the clutter ring, and resets the NOAREA flag to zero if the clutter ring is within the horizon. Through a call to subroutine SITPOS it determines the height of the radar antenna above the terrain. Then it determines the elevation angle corresponding to the bottom edge of the acceptance cone and subsequently the range to the intersection of the acceptance cone with the terrain (Equation [2.12-3]). If the range to the terrain intersection is beyond the radar horizon, the NOAREA flag is set to one and further clutter processing is inhibited. Otherwise it determines the ambiguity index of the minimum possible range (Equations [2.12-4] and [2.12-5]) and sets the NOAREA flag so that clutter processing continues.

Block 3. If the NOAREA flag is set to zero, subroutine DETGEO computes the range to the next range image (Equation [2.12-5]). If the range to the next range image is within the clutter horizon, the azimuth limits corresponding to the intersection of the acceptance cone with the terrain at the range of interest are computed (Equations [2.12-8] through [2.12-15]). DETGEO continues to loop through each range image within the clutter horizon.

Block 4. Subroutine SUMCLT prepares for integration of clutter returns from the current range ring by first clearing the accumulator variables for the intermediate clutter sums. It calls function ANGWDT to return the azimuth limits (Equations [2.12-14 and [2.12-15]) making sure the returned result falls between 0.0 degrees and 360 degrees. SUMCLT then divides the azimuth interval between the two azimuth limits into discrete clutter resolution cells, where the terrain resolution is defined by parameter RELEN (Equations [2.12-16] through [2.12-19]).

Next subroutine SUMCLT begins the integration of clutter returns for the current range ring. It sets the azimuth for the clutter cell and determines the XY clutter location in the ESAMS coordinate system.

Block 5. If native clutter mode has been selected by the user, the clutter reflectivity coefficient is determined using the logical flow shown in Figure 2.12-7.

Block 6. The native clutter use of digital terrain does not explicitly assess masking of the clutter patch by intervening terrain. To account for the reduced incidence of clutter returns due to terrain masking, the native mode uses a mean terrain clutter visibility factor (Equation [2.12-30]) to reduce the average clutter return signal (Equation [2.12-31]). The visibility factor, variable VIS, which is accessed by subroutine TLU, is tabulated for values of the difference in antenna and terrain height.

Block 7. If the user has selected the GRACE mode, clutter reflectivity and terrain masking are calculated using the logical flow as illustrated in Figure 2.12-8.

Block 8. Subroutine SUMCLT determines the relative X,Y,Z coordinates of the clutter cell. Subroutine FEND returns the antenna voltage gains in the direction of the clutter for the sum, elevation difference and azimuth difference. Fend determines the antenna gains in the direction of clutter with the antenna boresight pointed at the assumed target elevation and azimuth position.

Block 9. Subroutine SUMCLT sums partial computations of the total clutter power from each angle resolution cell, considering antenna gain and surface reflectivity, while preserving the signs of the difference channel voltage.

The final steps in subroutine SUMCLT is to compute the radial length of the clutter patch, which is the projection of the range gate at the clutter surface, which is multiplied by the summed partial clutter to fully account for the total area of the current clutter patch range ring. Finally, the clutter contribution of the current range ring is added to the clutter contributions from other range rings.

Block 10. Subroutine DETGEO increments the range ambiguity index and returns to Block 3 to execute the clutter computations for the next range ring. The process is repeated until clutter power has been accumulated from all range rings within the clutter horizon.

Block 11. Subroutine MGTOVO converts the total clutter signal powers in the sum and difference channels to complex voltage signals. The process used simply sets the phase angles to zero and converts the power to the real part of the complex voltage. (Equation [2.12-32])

### Native Clutter Mode

Figure 2.12-7 shows the functional flow for determination of clutter reflectivity when the native mode has been selected.

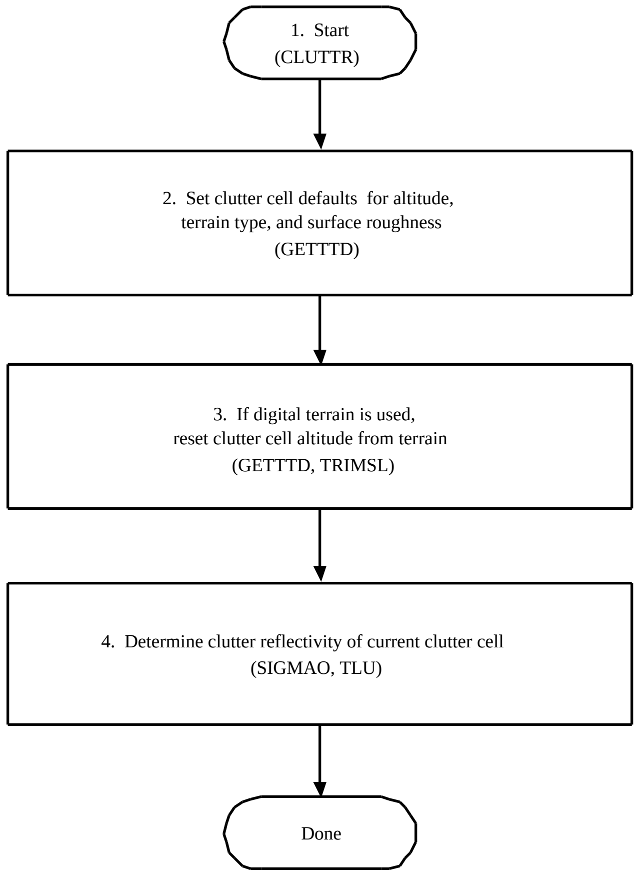



FIGURE 2.12-7. Reflectivity Functional Flow — Native Mode.

Block 1. In the native mode, after clutter resolution cells have been defined, subroutine SUMCLT calls subroutine GETTTD to get the terrain data necessary to calculate reflectivity.

Block 2. Subroutine GETTTD gets terrain data from data arrays based upon user defined values of terrain roughness and terrain type. The subroutine first sets default values for the altitude of the clutter cell (in ESAMS coordinates), for the terrain roughness and the terrain type. The clutter type index and the terrain roughness value remain at these values regardless of whether or not digital terrain is being used.

Block 3. If the flag for using digital triangular is set, subroutine GETTTD resets the terrain altitude to that of the digital terrain. It does this through the use of the GRACE triangular terrain generator (TTG), utility subroutines CHGC2S, GETSQR, and TRIMSL. Subroutine CHGC2S converts the ESAMS XY coordinates for the clutter cell to geographic latitude and longitude coordinates. Then subroutine GETSQR brings in the triangular terrain data square that contains the geographical coordinates of the clutter cell. Finally, subroutine TRIMSL determines the altitude above mean sea level of the clutter cell from the triangular terrain data and converts it to the ESAMS Z coordinate. GRACE and its support subroutines are not a part of the clutter function and will not be described in detail for this functional element.

Block 4. Subroutine SIGMAO returns the clutter cell surface reflectivity as a function of the terrain clutter type, the range of the clutter cell, the terrain roughness, the height of the terrain, the radar antenna height, and the setting of the wet terrain flag. Subroutine SIGMAO first calculates the grazing angle, which is set equal to the radar antenna depression angle to the clutter cell (Equation [2.12-22]). If the depression angle is negative, the depression angle is set to a very small positive angle.

To determine the terrain reflectivity, the user can select one of twelve indices of terrain type. Terrain type 1 is described as Georgia Tech sea clutter. The clutter is computed using Equations [2.12-23] through [2.12-28]. Terrain types 2 through 9 are designated as Georgia Tech land clutter types. The terrain reflectivity is computed using an empirical expression (Equation [2.12-29]. If the flag for wet terrain is set, the reflectivity for all cases (2 through 9) is increased by a factor of 5.0 dB. The parameters used for the computation of clutter types 2 through 9 are listed in Table 2.12-1, Georgia Tech Clutter Model Parameters.

Terrain types 10 through 12 are designated as Lincoln Laboratory clutter cases. In these cases the reflectivity, in the form of a look-up table, is accessed through utility subroutine TLU. The parameters used for the determination of reflectivity for terrain types 10 through 12 are listed in Table 2.12-2.

After the surface reflectivity is calculated, program control returns to Block 6 of Figure 2.12-6.

### GRACE Clutter Mode

Figure 2.12-8 shows the functional flow for determination of surface reflectivity when the GRACE clutter mode has been selected.

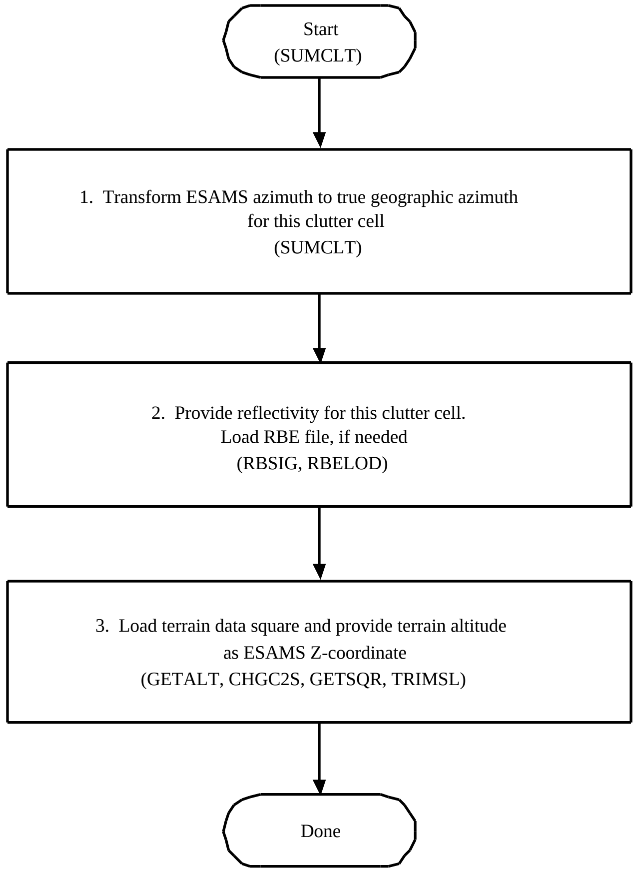



FIGURE 2.12-8. Reflectivity Functional Flow — GRACE Mode.

<u>Block 1</u>. In GRACE mode, after clutter resolution cells have been defined (Figure 2.12-9, Block 4), subroutine SUMCLT converts the ESAMS azimuth position of the clutter cell to true azimuth used in the geographical data of GRACE (Equation [2.12-33]).

<u>Block 2</u>. Subroutine SUMCLT calls subroutine RBSIG with the range and true azimuth of the clutter cell to retrieve the clutter reflectivity of the specific clutter cell from the GRACE RBE data. It retrieves, from the RBE Sigma file data, the value of reflectivity stored in this data structure for the specific terrain point specified by the range and true azimuth relative to the radar site location. Unlike the native mode which estimates a loss factor to account for terrain masking of the clutter patch by intervening terrain, GRACE clutter masking is explicitly calculated. To create the RBE Sigma file, GRACE first creates a site mask map from the surrounding terrain using the Site Masking Generator (SMG). Then a backscatter coefficient is calculated for each resolution cell within the visible regions of the surface using the RF Backscatter Estimator (RBE). If the RBE Sigma file data have not already been loaded, RBSIG calls subroutine RBELOD to load the data from the off-line Sigma file. RBSIG is a part of the GRACE and is not a part of ESAMS functionality, so it will not be discussed in more detail.

<u>Block 3</u>. Subroutine SUMCLT calls subroutine GETALT to obtain the height of the terrain cell in the ESAMS coordinate system. Subroutine GETALT first sets the altitude of the

terrain to a default value. If the triangular terrain flag is on, GETALT resets the clutter cell terrain altitude to that for the digital terrain. It does this through the use of GRACE Triangular Terrain Generator (TTG) utility subroutines CHGC2S, GETSQR, and TRIMSL. Subroutine CHGC2S transforms the ESAMS XY coordinates to geographical latitude and longitude. Subroutine GETSQR is then called to retrieve the triangular terrain data that surrounds the cell latitude and longitude. Finally subroutine TRIMSL retrieves the clutter cell altitude above mean sea level from the terrain data and converts the cell altitude to ESAMS coordinates.

Subroutines CHGC2S, GETSQR, and TRIMSL are part of GRACE functionality and will not be described in further detail.

### Subroutine Flow Charts

The logical implementation details of the Clutter Functional Flow are presented below. Figure 2.12-9 depicts the logical flow of CLUTTR, the main subroutine in the implementation of clutter. Figures 2.12-10 through 2.12-17 depict the logical flow of the other major subroutines implementing this FE. These diagrams contain additional logical details of the functional flows described above.

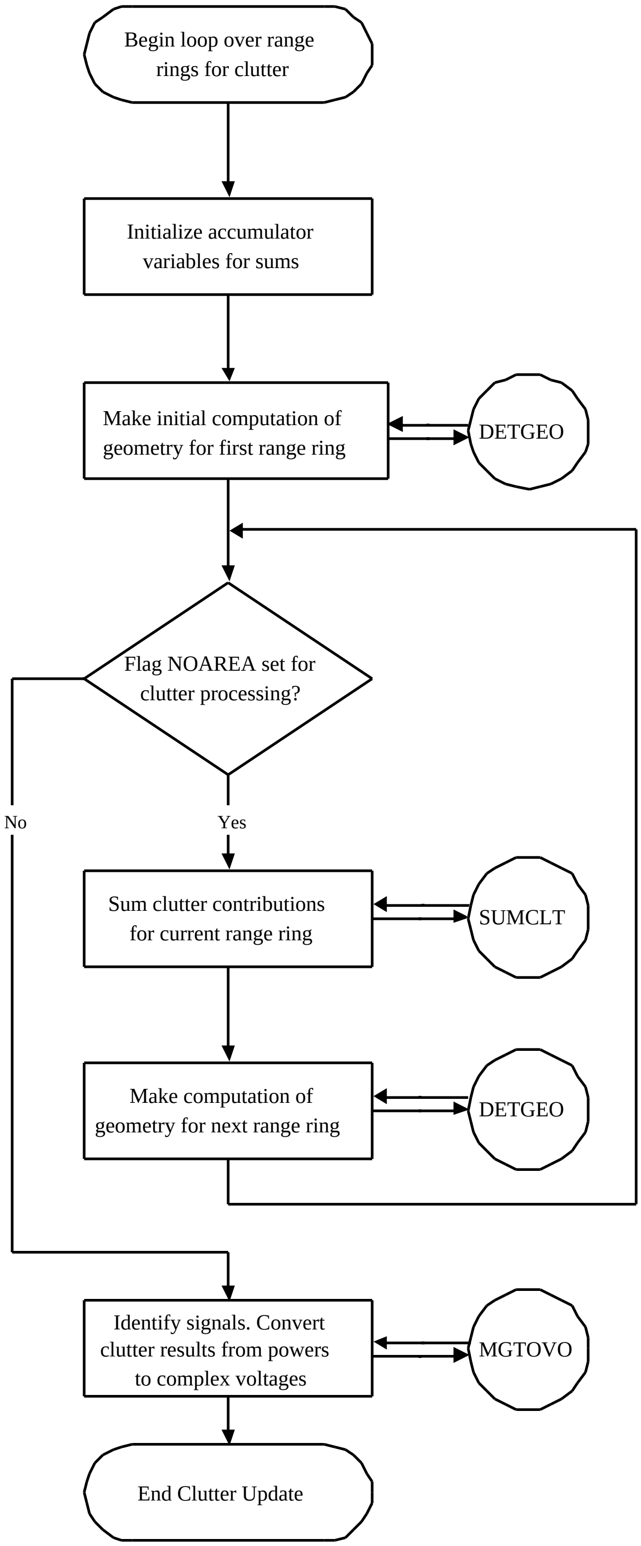



FIGURE 2.12-9. Clutter Update Functional Flow — Range Ring Loop in CLUTTR (Native and GRACE).

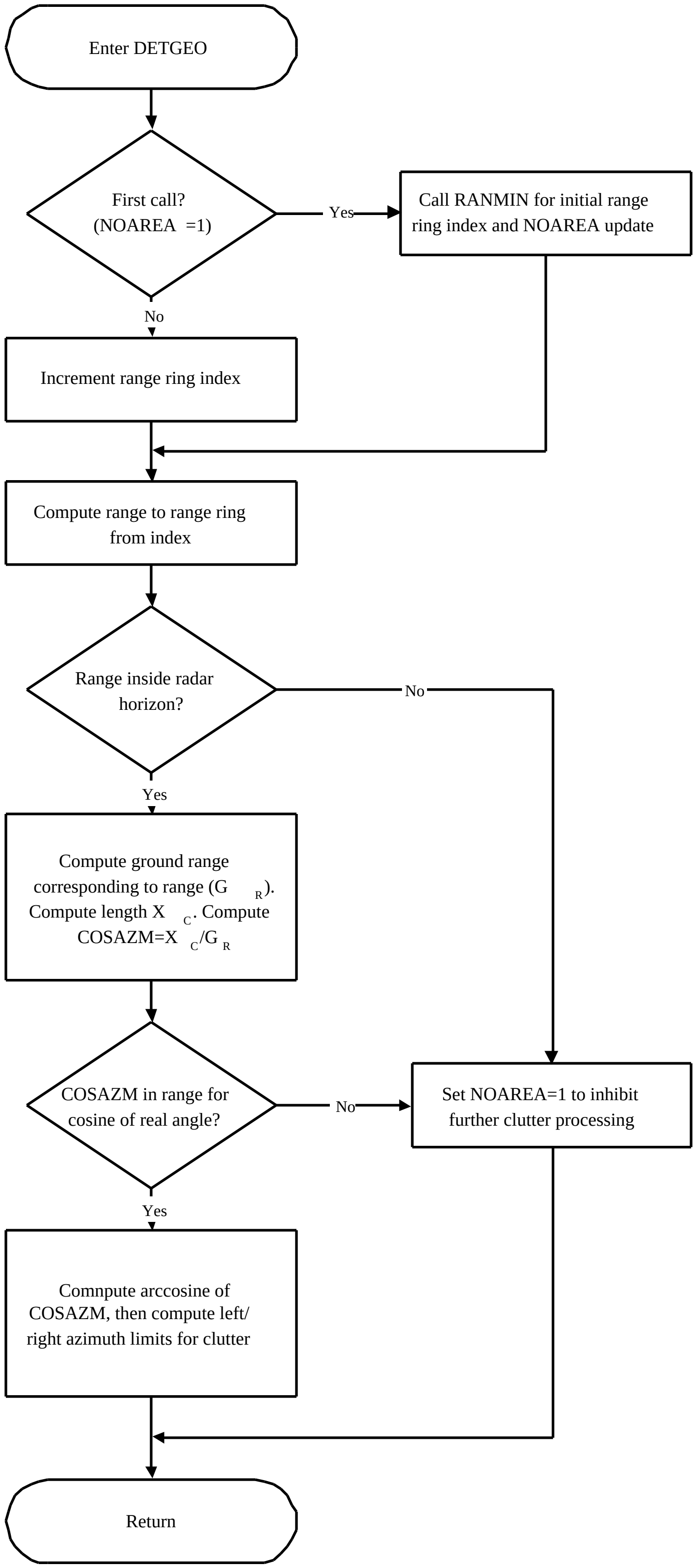



FIGURE 2.12-10. Clutter Update Functional Flow — Subroutine DETGEO (Native and GRACE).

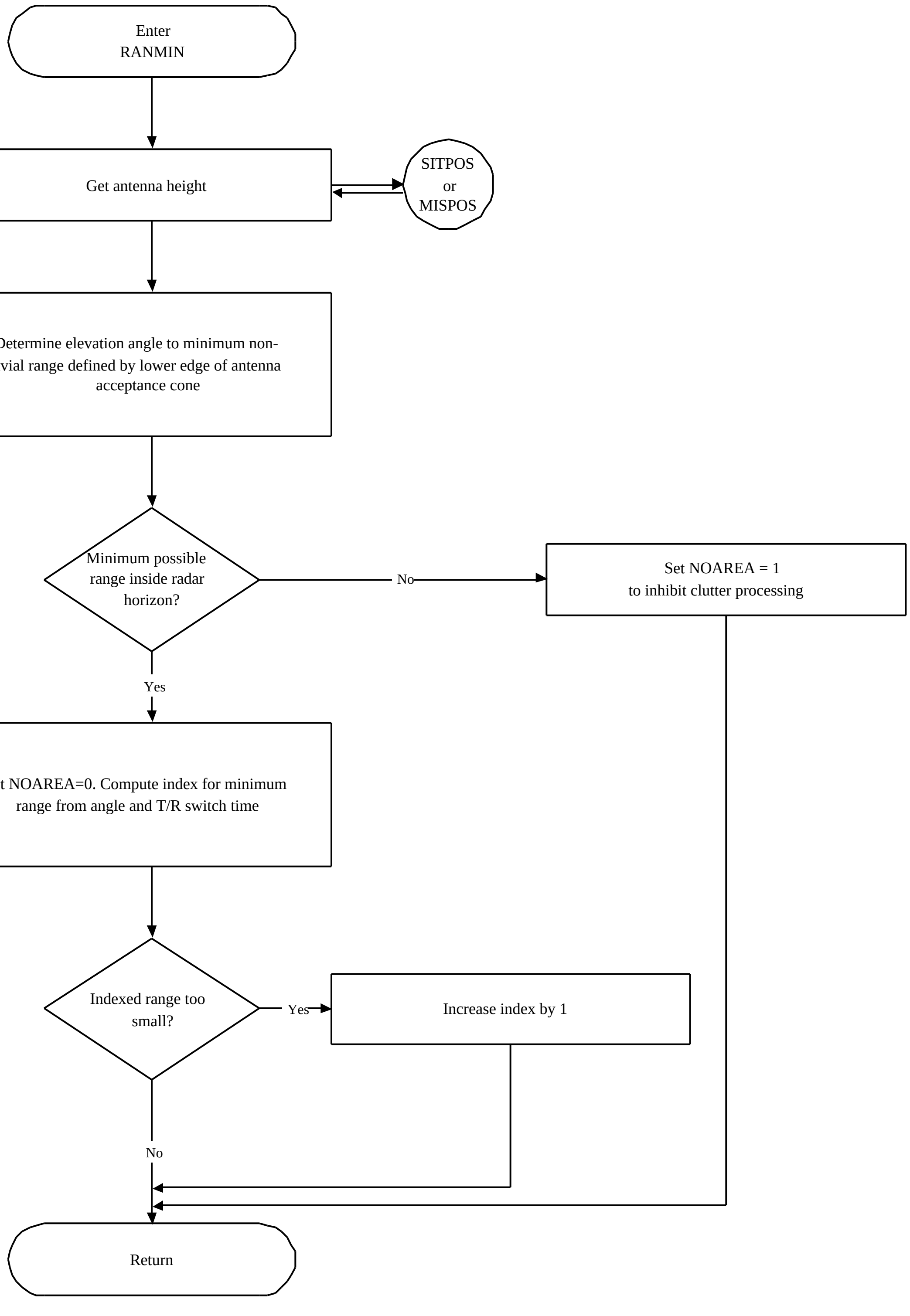



FIGURE 2.12-11. Clutter Update Functional Flow — Subroutine RANMIN (Native and GRACE).

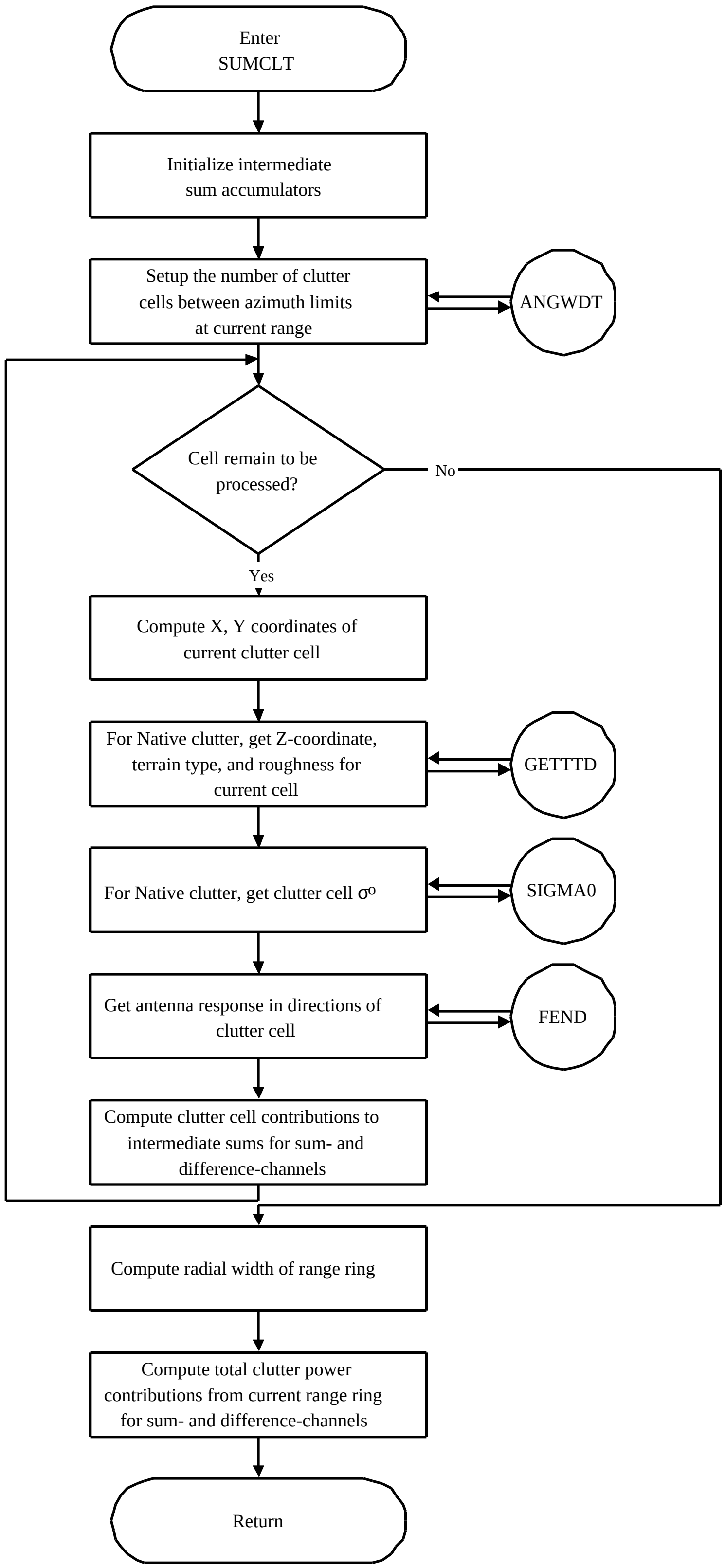



FIGURE 2.12-12. Clutter Update Functional Flow — Subroutine SUMCLT (Native Part Only).

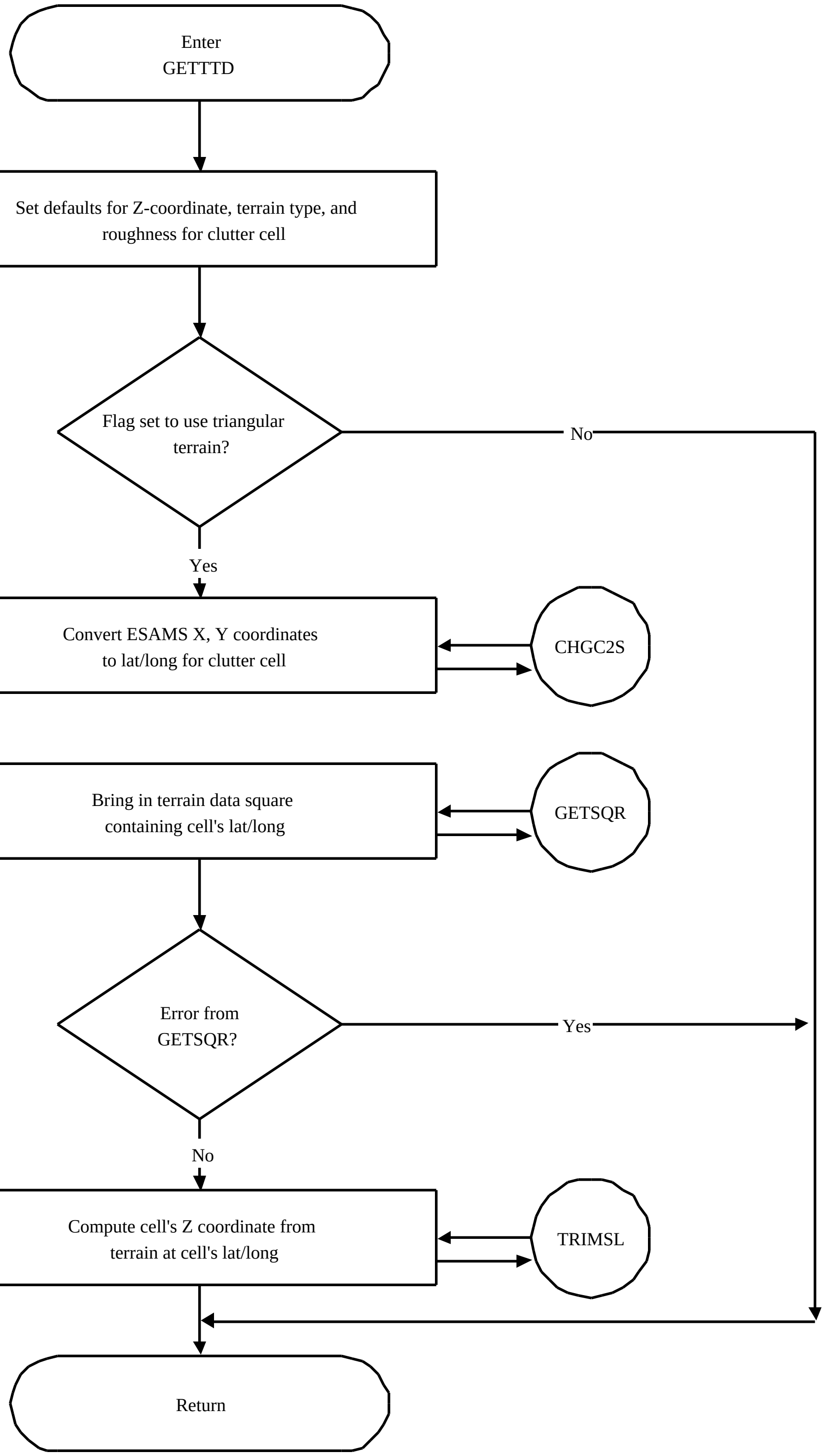



FIGURE 2.12-13. Clutter Update Functional Flow — Subroutine GETTTD
(Native Part Only).

DRAFT

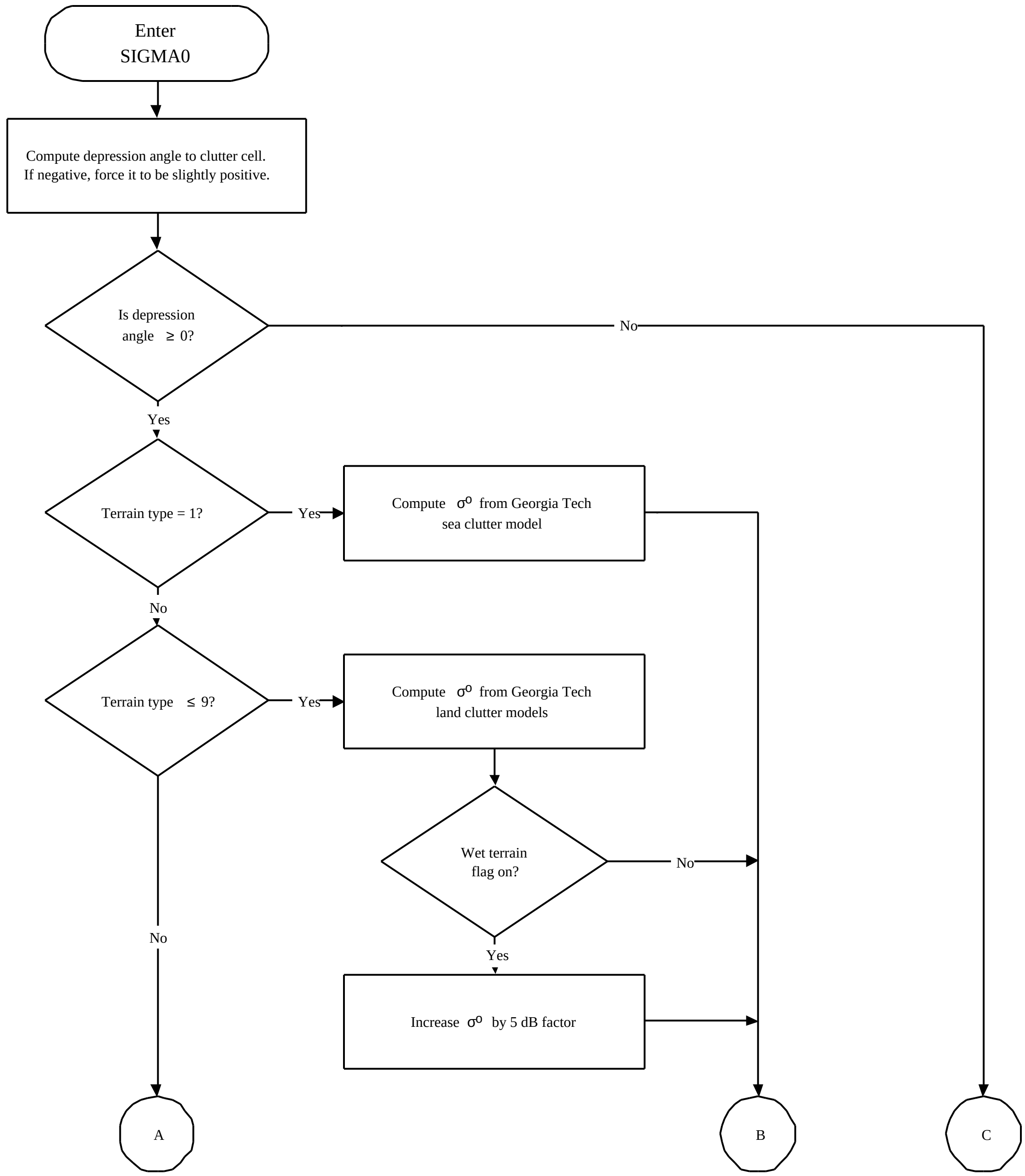




FIGURE 2.12-14a. Clutter Update Functional Flow — Subroutine SIGMAO (Native Only).


DRAFT

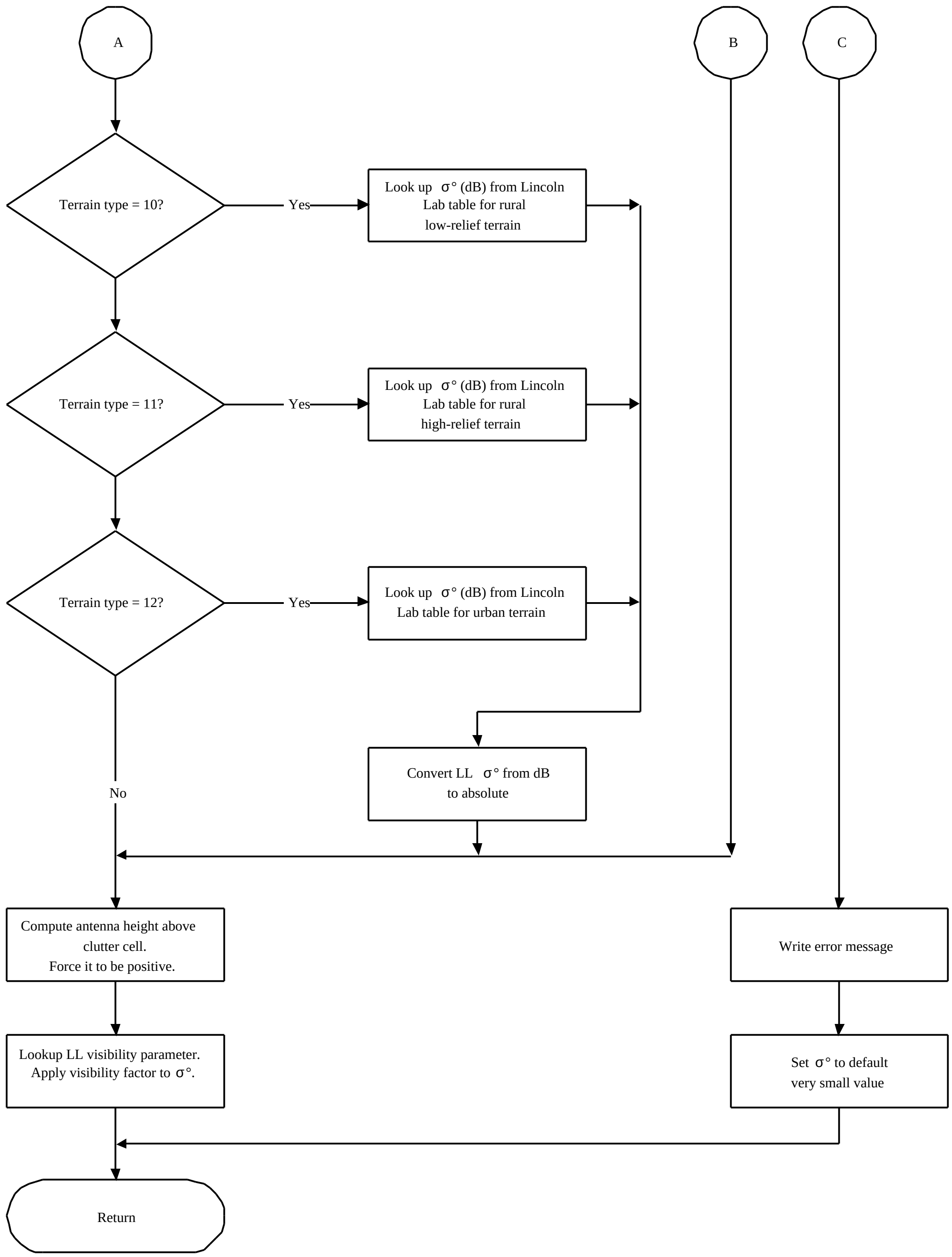



FIGURE 2.12-14b. Clutter Update Functional Flow — Subroutine SIGMAO (Native Only). (Concluded)

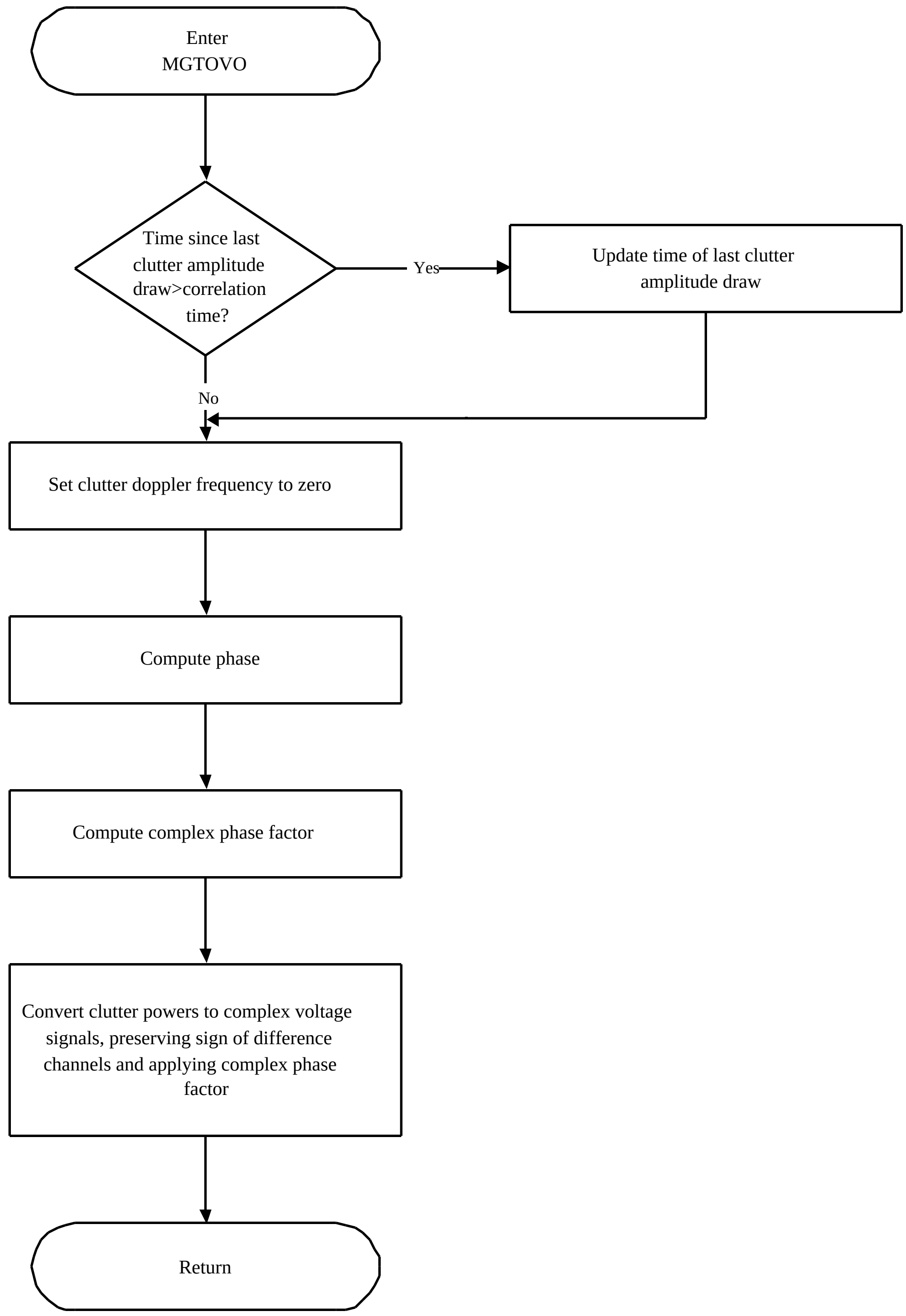



FIGURE 2.12-15. Clutter Update Functional Flow — Subroutine MGTOVO (Native and GRACE).

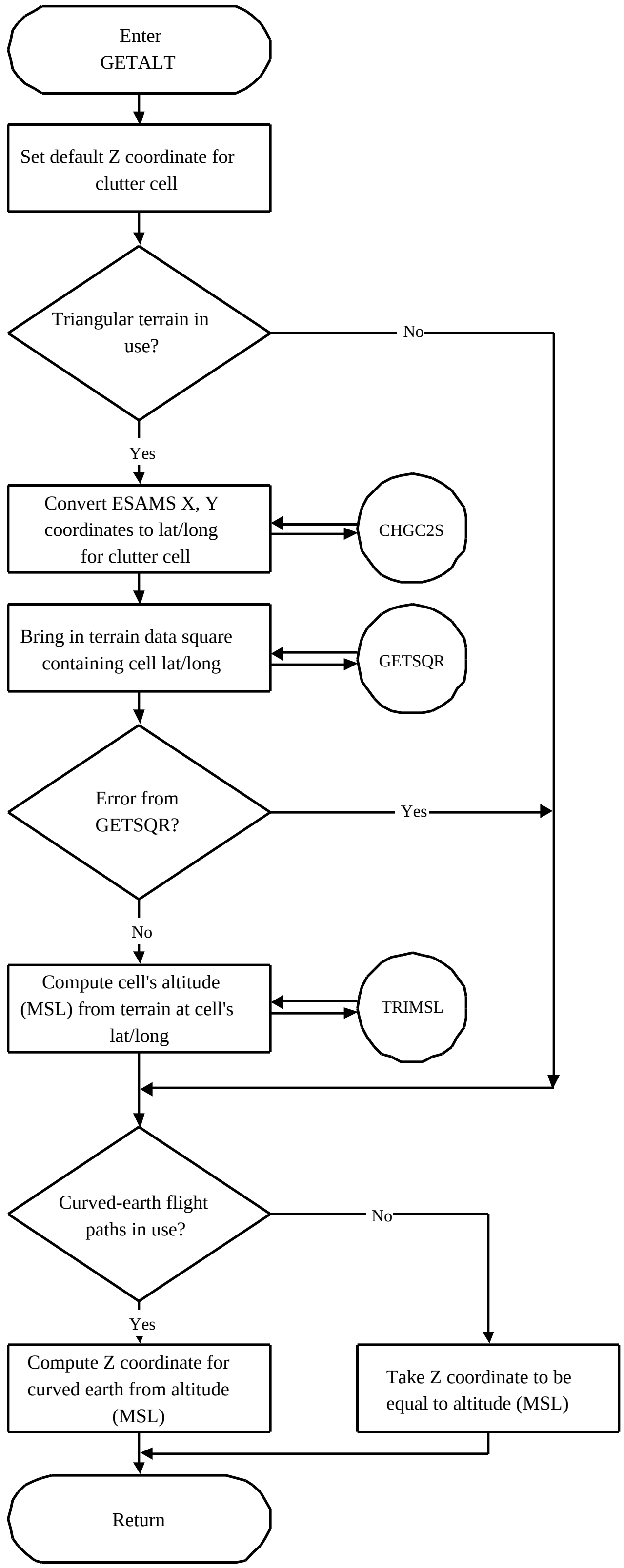



FIGURE 2.12-16. Clutter Update Functional Flow — Subroutine GETALT (GRACE Only).

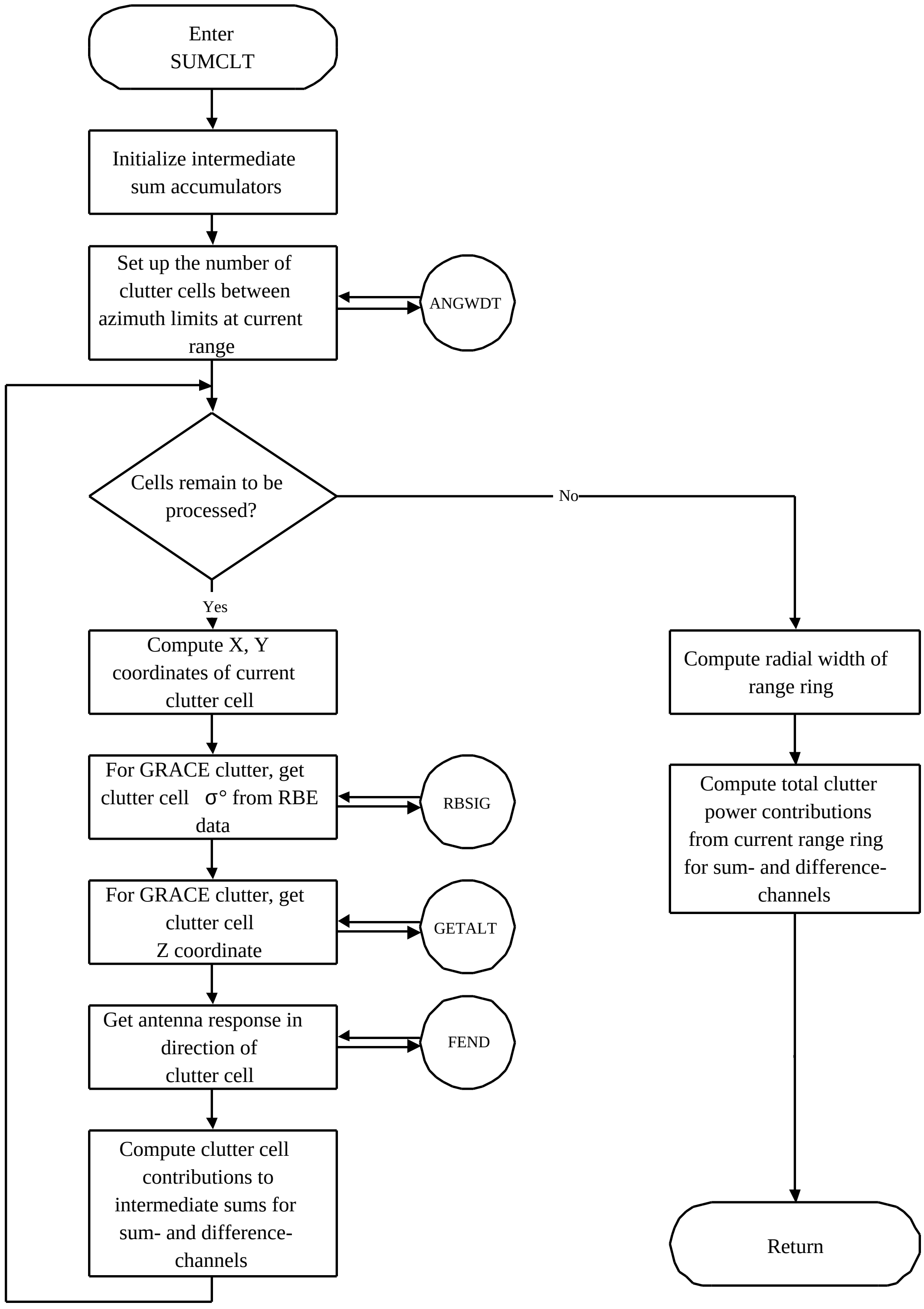



FIGURE 2.12-17. Clutter Update Functional Flow — Subroutine SUMCLT (GRACE Part Only).

## Clutter Inputs and Outputs

The model inputs that affect the Clutter Functional Element are listed in Table 2.12-4.

TABLE 2.12-4. Clutter Model Inputs.

| Variable Name | Description |
|---|---|
| TTYPE | Default terrain type |
| TERRF | Default terrain roughness |
| TERZ | Default terrain height |
| XKCLFL | Clutter selection array |
| WET | Wet terrain flag |
| ANTGN | Antenna gain table |
| XPWRTX | Transmitter power |
| XTRGW | Range gate width |
| XUNPRF | Unambiguous pulse repetition frequency |
| XWVLTX | Wave length of transmitter frequency |
| ITERA | Digital terrain data |
| A | Clutter reflectivity model coefficient for several frequencies and terrain types |
| ANGOFF | Maximum angle off of boresight for clutter calculations |
| B | Clutter reflectivity model coefficient for all frequencies and several terrain types |
| C | Clutter reflectivity model coefficient for all frequencies and several terrain types |
| CELMAX | Maximum antenna boresight elevation for clutter tables |
| CELMIN | Minimum antenna boresight elevation for clutter tables |
| CLINTV | Clutter update interval |
| D | Clutter reflectivity model coefficient for all frequencies and several terrain types |
| DELEL | Elevation resolution for clutter tables |
| DELRNG | Range resolution for clutter tables |
| RELEN | Terrain resolution of clutter resolution |
| RUHILL | Lincoln Lab Rural High-Terrain reflectivity values |
| RULOLL | Lincoln Labs Rural Low-Terrain reflectivity values |
| TAUCLT | Correlation time for clutter magnitude draws |
| URBNLL | Lincoln Labs Urban Terrain reflectivity values |
| VISPAR | Visibility parameter table |

The outputs of the Clutter Functional Element are the sum and difference channel clutter signal voltages as listed in Table 2.12-5.

TABLE 2.12-5. Clutter Outputs.

| Variable Name | Description |
|---|---|
| SGDVA | Array of clutter signal azimuth channel voltages |
| SGDVE | Array of clutter signal elevation channel voltages |
| SGSV | Array of clutter signal sum channel voltages |

Inputs and outputs for the principal subroutines which directly implement the clutter functional element are given in Tables 2.12-6 through 2.12-21.

TABLE 2.12-7. Subroutine ANTPAT Inputs and Outputs.

| **SUBROUTINE: ANTPAT** | | | | | |
|---|---|---|---|---|---|
| **Inputs** | | | **Outputs** | | |
| **Name** | **Type** | **Description** | **Name** | **Type** | **Description** |
| ANTPT1 | Common RDRD | Pointer to antenna indicating start of table lookup | GDIFAZ | Argument | Difference gain, Azimuth |
| ANTPT2 | Common RDRD | Pointer to antenna indicating start of table lookup | GDIFEL | Argument | Difference gain, Elevation |
| ANTPT3 | Common RDRD | Pointer to antenna indicating start of table lookup | GSUM | Argument | Sum gain |
| DTR | Common CONST | Converts degrees to radians | | | |
| GDIFAZ | Argument | Difference gain, Azimuth | | | |
| GDIFEL | Argument | Difference gain, Elevation | | | |
| GSUM | Argument | Sum gain | | | |
| RANGE | Argument | Distance from site to point of interest | | | |
| XAT | Argument | Radar to target X coordinate in antenna frame | | | |
| YAT | Argument | Radar to target Y coordinate in antenna frame | | | |
| ZAT | Argument | Radar to target Z coordinate in antenna frame | | | |

TABLE 2.12-6. Subroutine ANGWDT Inputs and Outputs.

| **SUBROUTINE: ANGWDT** | | | | | |
|---|---|---|---|---|---|
| **Inputs** | | | **Outputs** | | |
| **Name** | **Type** | **Description** | **Name** | **Type** | **Description** |
| ARG1 | Argument | Angle 1 | ANGWDT | Function | Difference between angle 1 and angle 2 |
| ARG2 | Argument | Angle 2 | | | |
| EPSILN | Common CONST | A very small number | | | |
| PIX2 | Common CONST | 2p | | | |

TABLE 2.12-8. Subroutine CLUTTR Inputs and Outputs.

**SUBROUTINE: CLUTTR**

| **Inputs** | | | **Outputs** | | |
|---|---|---|---|---|---|
| **Name** | **Type** | **Description** | **Name** | **Type** | **Description** |
| ATNMTI | Common GRADAR | Attenuation for MTI in notch (dB) | IDCLUT | Common CLUVAR | Clutter ID for Bus |
| BIGNUM | Common CONST | A very large number | NEWCLT | Argument | Flag indicating clutter calculated |
| CLTEPS | Common MULC | Minimum clutter power for consideration | PWCL | Common CLUVAR | Clutter pulse width |
| CLTINTV | Common MULC | Update clutter contribution | RSCL | Common CLUVAR | Site to clutter distance |
| GDT | Common GRADAR | System time increment (sec) | SUMMAG | Argument | Magnitude of clutter in the sum channel |
| IACQR | Common ARYBND | Acquired radar — flag | | | |
| IBIN | Argument | The bin in the CFAR MASD being processed | | | |
| IGRACE | Common TERNDR | GRACE mode - flag<br>0 = Use Native Mode<br>1 = Use GRACE Mode | | | |
| IRADAR | Argument | Radar index | | | |
| IRADFL | Common FLAGS | Radar type flag:<br>1 = ACQ<br>2 = TRACK<br>3 = SEEK<br>4 = ILLUM | | | |
| KCLFL | Common FLAGS | Clutter select flag<br>1 = Area Clutter<br>IQUICK = “Quick” Clutter | | | |
| NOAREA | Common CLTIN | 1 = No more area left to examine<br>0 = More Area Left to examine | | | |
| NUMTAR | Common ARYBND | Number of possible target signals | | | |
| RGATES | Common GRADAR | Range gate center | | | |
| TIMEG | Common GRADAR | Simulation time (sec) | | | |
| TLASTC | Common CLTIN | Last time for clutter evaluation | | | |
| TRGW | Common SVOVAR | Range gate width (sec) | | | |

TABLE 2.12-9. Subroutine CIRC Inputs and Outputs.

| SUBROUTINE: CIRC | | | | | |
|---|---|---|---|---|---|
| **INPUTS** | | | **OUTPUTS** | | |
| **NAME** | **TYPE** | **DESCRIPTION** | **NAME** | **TYPE** | **DESCRIPTION** |
| ANTPT1 | Common RDRD | Pointer to antenna gain indicating start of table look-up | GAINC | Argument | Gain of circular beam |
| DTR | Common CONST | Converts degrees to radians | IFIRST | Argument | Initialization control variable |
| EPSILN | Common CONST | A very small number | | | |
| HPANG | Argument | Half power angle | | | |
| ICALC | Argument | Gain flag:<br>0 = calculate gain<br>1 = Table look-up | | | |
| IFIRST | Argument | Initialization control variable | | | |
| RANGE | Argument | Distance from site to point of interest | | | |
| ROTATE | Argument | Rotation angle around beam axis | | | |
| SQUINT | Argument | Squint angle | | | |
| XAT | Argument | X coordinate of point of interest relative to antenna coordinates | | | |
| YAT | Argument | Y coordinate point of interest relative to antenna coordinates | | | |
| ZAT | Argument | Z coordinate point of interest relative to antenna coordinates | | | |

TABLE 2.12-10. Subroutine DETGEO Inputs and Outputs.

| SUBROUTINE: DETGEO | | | | | |
|---|---|---|---|---|---|
| **Inputs** | | | **Outputs** | | |
| **Name** | **Type** | **Description** | **Name** | **Type** | **Description** |
| BOREAZ | Common FREND | Boresight azimuth angle | AZMAX | Argument | Left side clutter patch boundary azimuth angle |
| BOREEL | Common FREND | Boresight elevation angle | AZMIN | Argument | Right side clutter patch boundary azimuth angle |
| COSANG | Common CLUVAR | Cosine of ‘angoff,’ array | GRANG E | Argument | Ground range to center of the clutter patch |
| IPRI | Common GRADAR | Active PRI | RANGE | Argument | Range to the center of the clutter patch |

TABLE 2.12-10. Subroutine DETGEO Inputs and Outputs. (Contd.)

| SUBROUTINE: DETGEO | | | | | |
|---|---|---|---|---|---|
| **Inputs** | | | **Outputs** | | |
| **Name** | **Type** | **Description** | **Name** | **Type** | **Description** |
| IRADAR | Argument | Index to radar number | | | |
| NOAREA | Common CLTIN | No more area left to examine — flag | | | |
| PRI | Common GRADAR | Intervals between pulses used by RADAR in PRI modes. | | | |
| RANHOR | Common CLTIN | Distance to the radar horizon from the antenna | | | |
| RGATES | Common GRADAR | Range gate center | | | |
| SPDLGT | Common CONST | Speed of light | | | |
| ZSJ | Common RUNVR | TTR antenna Z coordinate in ICS | | | |

TABLE 2.12-11. Subroutine DIFSUM Inputs and Outputs.

| SUBROUTINE: DIFSUM | | | | | |
|---|---|---|---|---|---|
| **Inputs** | | | **Outputs** | | |
| **Name** | **Type** | **Description** | **Name** | **Type** | **Description** |
| BMGAIN | Argument | Gain of individual beams | GDIFAZ | Argument | Azimuth difference channel response |
| GAIN | Argument | Array of relative gains of 4 beams | GDIFEL | Argument | Elevation difference channel response |
| SNORM | Argument | Sum gain normalization factor | GSUM | Argument | Sum channel response |
| | | | SNORM | Argument | Sum gain normalization factor |

TABLE 2.12-12. Subroutine FEND Inputs and Outputs.

| SUBROUTINE: FEND | | | | | |
|---|---|---|---|---|---|
| **Inputs** | | | **Outputs** | | |
| **Name** | **Type** | **Description** | **Name** | **Type** | **Description** |
| ALPOFF | Argument | Angle of directrix off of PHI scan intersection | GDIFAZ | Argument | Difference pattern in azimuth |
| ANGCNT | Common TWSANC | Angle gate center | GDIFEL | Argument | Difference pattern in elevation |
| BMGAIN | Argument | Gain of individual beams | GSUM | Argument | Sum of gains of 4 beams |
| BOREAZ | Argument | Boresight azimuth angle | RANGE | Argument | Distance from site to point of interest |

TABLE 2.12-12. Subroutine FEND Inputs and Outputs. (Contd.)

| **SUBROUTINE: FEND** | | | | | |
|---|---|---|---|---|---|
| **Inputs** | | | **Outputs** | | |
| **Name** | **Type** | **Description** | **Name** | **Type** | **Description** |
| BOREEL | Argument | Boresight elevation angle | | | |
| EPSILN | Common CONST | A very small number | | | |
| GATWID | Common TWSANC | Angle gate width | | | |
| GDIFAZ | Argument | Difference pattern in azimuth | | | |
| GDIFEL | Argument | Difference pattern in elevation | | | |
| GSUM | Argument | Sum of gains of 4 beams | | | |
| HPANG | Argument | Half power angle for circular beam | | | |
| HPANGA | Argument | Azimuth half power angle for non-circular beam | | | |
| HPANGE | Argument | Elevation half power angle for non-circular beam | | | |
| HPOWER | Argument | Half power angle for non-circular beam | | | |
| ICALC | Argument | Calculation flag | | | |
| IRADFL | Argument | Radar type flag:<br>1 = ACQ<br>2 = TRACK<br>3 = SEEK<br>4 = ILLUM | | | |
| ISIGN | Common TWSANC | Scan bar flag | | | |
| NOUT | Argument | Logical unit number for output | | | |
| ROTB | Argument | Array of rotation angles for 4 beams | | | |
| SNORM | Argument | Sum gain normalization factor | | | |

TABLE 2.12-12. Subroutine FEND Inputs and Outputs. (Contd.)

**SUBROUTINE: FEND**

| **Inputs** | | | **Outputs** | | |
|---|---|---|---|---|---|
| **Name** | **Type** | **Description** | **Name** | **Type** | **Description** |
| SQANG | Argument | Array of squint angles for 4 beams | | | |
| TWSPTR | Common TWSANC | | | | |
| XAT | Argument | Body frame radar to point X-coordinate | | | |
| XIN | Argument | Inertial frame radar to point X-coordinate | | | |
| YAT | Argument | Body frame radar to point Y-coordinate | | | |
| YIN | Argument | Inertial frame radar point Y-Coordinate | | | |
| ZAT | Argument | Body frame radar point Z-coordinate | | | |
| ZIN | Argument | Inertial frame radar point Z-coordinate | | | |

TABLE 2.12-13. Subroutine GETALT Inputs and Outputs.

**SUBROUTINE: GETALT**

| **Inputs** | | | **Outputs** | | |
|---|---|---|---|---|---|
| **Name** | **Type** | **Description** | **Name** | **Type** | **Description** |
| ITERSW | Common TERNDR | Triangular terrain flag | ZPT | Argument | Tangent plane Z-coordinate of MSL object |
| IVAL | Common TERNDR | Initial default value array for terrain altitude, type ,and roughness | | | |
| KURVED | Common TERNDR | Curved earth flight paths — flag | | | |
| REARTH | Common CONST | Radius of the earth | | | |
| XPT | Argument | Cartesian coordinate | | | |
| YPT | Argument | Cartesian coordinate | | | |

TABLE 2.12-14. Subroutine GETTTD Inputs and Outputs.

**SUBROUTINE: GETTTD**

| Inputs | | | Outputs | | |
|---|---|---|---|---|---|
| **Name** | **Type** | **Description** | **Name** | **Type** | **Description** |
| ITERSW | Common TERNDR | Determines if digital terrain is being used — flag | ITRTYP | Argument | Terrain clutter type index |
| IVAL | Common TERNDR | Initial default value array for terrain altitude, type, and roughness | RUFNES | Argument | Terrain roughness parameter |
| PTLAT | Argument | Latitude of point | VECNRM | Argument | Dummy array |
| PTLON | Argument | Longitude of point | ZPT | Argument | Z coordinate of the clutter cell |
| XPT | Argument | X coordinate of the clutter cell | | | |
| YPT | Argument | Y coordinate of the clutter cell | | | |

TABLE 2.12-15. Subroutine GYRATE Inputs and Outputs.

**SUBROUTINE: GYRATE**

| Inputs | | | Outputs | | |
|---|---|---|---|---|---|
| **Name** | **Type** | **Description** | **Name** | **Type** | **Description** |
| IWAY | Argument | Flag indicating whether to trans. from body | X2 | Argument | X-coordinate in transformed system |
| PITCH | Argument | Pitch Euler angle relating the system | Y2 | Argument | Y-coordinate in transformed system |
| ROLL | Argument | Roll Euler angle relating the system | Z2 | Argument | Z-coordinate in transformed system |
| X1 | Argument | X-coordinate in original system | | | |
| Y1 | Argument | Y-coordinate in original system | | | |
| YAW | Argument | Yaw Euler angle relating the system | | | |
| Z1 | Argument | Z-coordinate in original system | | | |

TABLE 2.12-16. Subroutine MGTOVO Inputs and Outputs.

**SUBROUTINE: MGTOVO**

| **Inputs** | | | **Outputs** | | |
|---|---|---|---|---|---|
| **Name** | **Type** | **Description** | **Name** | **Type** | **Description** |
| PCLTAZ | Argument | Clutter signed power sum in azimuth channel | DAZCLT | Argument | Clutter complex in voltage in azimuth channel |
| PCLTEL | Argument | Clutter signed power sum in elevation channel | DELCLT | Argument | Clutter complex in voltage in elevation channel |
| PCLTSM | Argument | Clutter power sum in the sum channel | SMCLT | Argument | Clutter complex in voltage in sum channel |
| PIX2 | Common CONST | $2\pi$ | TLAST | Argument | Clutter last temporal amplitude draw |
| TAUCLT | Argument | Clutter complex voltage in azimuth channel | | | |
| TIMEG | Common GRADAR | Simulation time (sec) | | | |
| TLAST | Argument | Clutter last temporal amplitude draw | | | |

TABLE 2.12-17. Subroutine NNCIRC Inputs and Outputs.

**SUBROUTINE: NNCIRC**

| **Inputs** | | | **Outputs** | | |
|---|---|---|---|---|---|
| **Name** | **Type** | **Description** | **Name** | **Type** | **Description** |
| ANTPT1 | Common RDRD | Pointer into antenna gain table indicating start of table look-up | GAINNC | Argument | Gain of non-circular beam |
| DTR | Common CONST | Converts degrees to radians | IFIRST | Argument | Initialization control variable |
| EPSILN | Common CONST | A very small number | HPOWER | Argument | Half power angle for non-circular beam |
| HPANGA | Argument | Azimuth half power angle for non-circular beam | | | |
| HPANGE | Argument | Elevation half power angle for non-circular beam | | | |
| ICALC | Argument | Method of obtaining antenna gains | | | |
| IFIRST | Argument | Initialization control variable | | | |
| IRADFL | Argument | Radar type flag:<br>1 = ACQ<br>2 = Track<br>3 = Seek<br>4 = Illum | | | |

TABLE 2.12-17. Subroutine NNCIRC Inputs and Outputs. (Contd.)

| **SUBROUTINE: NNCIRC** | | | | | |
|---|---|---|---|---|---|
| **Inputs** | | | **Outputs** | | |
| **Name** | **Type** | **Description** | **Name** | **Type** | **Description** |
| RANGE | Argument | Distance from site to point of interest | | | |
| ROTATE | Argument | Rotation angle around beam axis | | | |
| SQUINT | Argument | Squint angle | | | |
| XAT | Argument | X coordinate of point of interest relative to antenna coordinates | | | |
| YAT | Argument | Y coordinate of point of interest relative to antenna coordinates | | | |
| ZAT | Argument | Z coordinate of point of interest relative to antenna coordinates | | | |

TABLE 2.12-18. Subroutine RANMIN Inputs and Outputs.

| **SUBROUTINE: RANMIN** | | | | | |
|---|---|---|---|---|---|
| **Inputs** | | | **Outputs** | | |
| **Name** | **Type** | **Description** | **Name** | **Type** | **Description** |
| ANGOFF | Common MULC | Maximum angle off of boresight for clutter | IAMBIG | Argument | Index to range ambiguities |
| BOREEL | Common FREND | Boresight elevation angle | NOAREA | Common CLTIN | No more area left to examine — flag |
| DTR | Common CONST | Degrees to radian conversion factor | | | |
| IPRI | Common GRADAR | Active PRI | | | |
| IRADAR | Argument | Index to radar | | | |
| PRI | Common GRADAR | Pulse repetition interval | | | |
| RANGMN | Common CLTIN | Minimum range to clutter from switching consideration | | | |
| RGATES | Common GRADAR | Range gate center | | | |
| SPDLGT | Common CONST | Speed of light | | | |
| ZANT | Common CLUVAR | Antenna location Z coordinate | | | |

TABLE 2.12-19. Subroutine SIGMA0 Inputs and Outputs.

**SUBROUTINE: SIGMA0**

| Inputs | | | Outputs | | |
|---|---|---|---|---|---|
| **Name** | **Type** | **Description** | **Name** | **Type** | **Description** |
| A | Common MULC | Clutter model parameters for several frequencies | REFLEC | Argument | Clutter reflectivity |
| B | Common MULC | Clutter model parameters for all frequencies | | | |
| C | Common MULC | Clutter model parameters for all frequencies | | | |
| C4 | Common CLUTRR | Sea clutter constant | | | |
| C5 | Common CLUTRR | Sea clutter constant | | | |
| CLTEPS | Common MULC | Minimum clutter power for consideration | | | |
| D | Common MULC | Clutter model parameters for all frequencies | | | |
| EPSILN | Common CONST | A very small number | | | |
| ITTYPE | Argument | Type of terrain being used | | | |
| NOUT | Common FLAGS | Logical unit number fro simulation output | | | |
| RCLT | Argument | Range | | | |
| REFLEC | Argument | Clutter reflectivity | | | |
| RMSTRN | Argument | RMS terrain deviation | | | |
| ZANT | Argument | Z-coordinate of antenna | | | |
| ZCLUT | Argument | Z-coordinate of clutter | | | |
| WET | Argument | Wet terrain switch | | | |

TABLE 2.12-20. Subroutine SUMCLT Inputs and Outputs.

**SUBROUTINE: SUMCLT**

| Inputs | | | Outputs | | |
|---|---|---|---|---|---|
| **Name** | **Type** | **Description** | **Name** | **Type** | **Description** |
| AZMAX | Argument | Left side azimuth limit of the clutter patch | DFAPOW | Argument | Azimuth channel difference signed power |
| AZMIN | Argument | Right side of the clutter patch | DFEPOW | Argument | Elevation channel signed difference power |
| DFAPOW | Argument | Azimuth channel difference signed power | SUMPOW | Argument | Sum channel power sum |

TABLE 2.12-20. Subroutine SUMCLT Inputs and Outputs. (Contd.)

| SUBROUTINE: SUMCLT | | | | | |
|---|---|---|---|---|---|
| **Inputs** | | | **Outputs** | | |
| **Name** | **Type** | **Description** | **Name** | **Type** | **Description** |
| DFEPOW | Argument | Elevation channel difference signed power | | | |
| GRANGE | Argument | Ground range from TTR to clutter patch | | | |
| IGRACE | Common TERNDR | GRACE code in use - flag | | | |
| IRADAR | Argument | Radar flag | | | |
| PI | Common CONST | $\pi$ | | | |
| PIX2 | Common CONST | $2\pi$ | | | |
| POWCON | Common CLTIN | Radar power equation constants | | | |
| RANGE | Argument | Total range from the antenna to the clutter | | | |
| RELEN | Common MULC | Terrain resolution of clutter area | | | |
| SUMPOW | Argument | Sum channel power sum | | | |
| TRGW | Common SVOVAR | Range gate width in time units | | | |
| ZSJ | Common RUNVR | TTR antenna coordinate in ICS | | | |

TABLE 2.12-21. Subroutine TLU Inputs and Outputs.

| SUBROUTINE: TLU | | | | | |
|---|---|---|---|---|---|
| **Inputs** | | | **Outputs** | | |
| **Name** | **Type** | **Description** | **Name** | **Type** | **Description** |
| F | Argument | NT single table | F | Argument | NT single table |
| ILAST | Argument | Pointer to last place used in table | ILAST | Argument | Pointer to last place used in table |
| X | Argument | Independent variable | W | Argument | Value of dependent variable |

### 2.12.4 Assumptions and Limitations

In the native clutter mode, all terrain cells share common values of terrain type and surface roughness, hence a common value of terrain reflectivity. In the GRACE mode, each terrain cell has a unique value of terrain type and surface roughness.

For computation of the clutter area, the earth is assumed a flat surface.

When in the native mode, the choices of Lincoln Laboratory derived terrain reflectivity is limited to General Rural/Low-Relief, General Rural/High-Relief, and General Urban. In the GRACE mode, the complete array of Lincoln Lab terrain type is used to determine terrain reflectivity.

Site specific terrain masking is not explicitly modeled in the native mode. An empirically derived “clutter visibility” factor accounts for the statistical likelihood of clutter masking by intervening terrain.

The antenna depression angle from the radar antenna to the clutter terrain point is assumed as the grazing angle of incidence.

The radar horizon is computed assuming bare, spherical earth geometry with refraction correction using the four-thirds earth radius approximation, with the approximation that the radar antenna height is very small relative to the earth’s radius.

In the native mode only positive grazing angles are considered in computing terrain reflectivity. If the terrain is higher than the antenna, the grazing angle is set to a very small positive angle.